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The effect of varying the parameters of vane shear tests on marine sediments.

Singler, James Charles.

Monterey, California. Naval Postgraduate School

THE EFFECT OF VARYING THE PARAMETERS OF VANE SHEAR TESTS ON MARINE SEDIMENTS

by

James Charles Singler

United States
Naval Postgraduate School

THESIS

THE EFFECT OF VARYING THE PARAMETERS
OF
VANE SHEAR TESTS ON MARINE SEDIMENTS

James Charles Singler

Thesis Advisor: R. J. Smith

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The Effect of Varying the Parameters of

Vane Shear Tests on Marine Sediments

by

James Charles Singler
Lieutenant, United States Navy
B.S., United States Naval Academy, 1963

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ABSTRACT

The consequences resulting from varying the parameters of the vane shear test (used to determine the shear strength of marine sediments) were investigated. Experiment showed that larger ratios of container diameter to vane diameter yield more accurate shear strengths. It was also shown that the four-bladed vane produced the best results. Finally, rates of rotation of one and two revolutions per hour were found to give accurate values of shear strength, while higher rates of rotation proved to be unsatisfactory.

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ACKNOWLEDGEMENT

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I. INTRODUCTION

In recent years there has been an increase of interest by private industry and government agencies in determining the physical properties of the sediments of the ocean floor.

The shear strength of marine sediments can be measured by unconfined compression, direct shear, triaxial shear, and by vane shear tests. The first three of these tests usually require the removal of the sediment samples from a core liner, and may even require the placing of the sample into a special container for testing. This handling produces further disturbance to the sediment in addition to that which may already have been caused by the coring process.

A vane shear test circumvents these problems as the shear strength measurement can be performed in the core liner or even _in-situ_ [Smith, 1962]. Many variations in vane shear testing equipments exist, but all are based on the vane borer as developed in Sweden and Germany in 1928 and 1929 [Osterberg, 1957]. Cadling and Odenstad [1950] earlier reported on the use of a vane device for measuring the shear strength of terrestial clays. The device made use of a vane consisting of four rectangular blades and a calibrated spring to measure the maximum torque developed when the vane was turned in the clay.

Once the maximum torque was determined the equation of Cadling and Odenstad was used to calculate the shear strength:

$$S = \frac{M_{max}}{\left(\pi DH \frac{D}{2} + 2 \frac{\pi D^2}{4} \frac{2}{3} \frac{D}{2}\right)}$$

where M_{max} = maximum torsional moment required to produce shear,

D = diameter of the vane,

H = height of the vane.

The above equation assumes that the surface of the rupture consists of a circular cylinder with the same dimensions as the vane. Additionally, it is assumed that the stress distribution at the maximum torsional moment is uniform across the surface of the cylinder, including the ends.

The rate of rotation of the vane was reported by Cadling and Odenstad to have some effect on the shear strength values. Higher rates of rotation produced correspondingly higher shear strengths. A rotation rate of 0.1 degree per second (6 degrees per minute or 1 revolution per hour) was arbitrarily adopted as a standard, and this rate gave conservative results. A rate of 0.2 degree per second (two revolutions per hour) was used by Morelock [1967] based on the assumption that the value of shear strength obtained was very nearly the same as at the slower rate. Aas [1965] reports finding no significant changes in shear strength at rates ranging from 1 to 10 revolutions per hour.

A height to diameter ratio (H/D) of two was used by Cadling and Odenstad [1950]. Aas [1965] experimented with various H/D ratios

and concluded that results of the shear strength determinations were not greatly affected unless the H/D ratio exceeded a value of three. Osterberg [1957] suggested that the area of the vane should not be greater than ten per cent of the area of the sample to be tested.

Because of the many differences in the parameters of the vane shear test, further study into the effects of varying the parameters was thought to be necessary. The parameters chosen to be varied were the diameter of the container, the number of blades of the vane and the rate of rotation of the vane. The parameters of vane dimensions, H/D ratio, and container height were not varied. A study of the effect of varying the parameters would permit the evaluation of previous recommendations, the standardization of vane shear test procedures, and valid comparisons of results from different test facilities.

II. DESCRIPTION OF EQUIPMENT

The basic equipment used for testing was chosen because of its availability, versatility, and suitability for the tests which were performed. To vary the parameters, containers of different diameters, vanes with different numbered blades, and motors with different speeds of rotation were required.

A. GENERAL DESCRIPTION

Commercially available vane shear test devices have been made to specifications of various testing facilities. The Naval Postgraduate School (NPS) vane shear apparatus was used for all testing as it is the best equipment currently available in view of its adaptability to this investigation [Minugh, 1970].

The NPS vane shear apparatus consists of the following major components:

1. torque transducer,
2. power supply and signal conditioning unit,
3. motor and motor mount.

As originally constructed by Minugh and subsequently modified by Heck [1970], it utilizes the above components in conjunction with a stand and a height adjustment mechanism to lower and raise the vane into and out of the sample. The heavier laboratory stand as described by Minugh was used along with the height adjustment mechanism

developed by Heck for this testing program. Holes were tapped in the base of the stand to hold the various sizes of sample containers. The complete test apparatus is shown in Figure 1. A strip recorder and an x-y plotter were used to record various portions of the results of the tests.

B. COMPONENTS

1. Torque Transducer

The torque transducer selected by Minugh has a range of 0-250 inch-ounces and may be over-torqued 100 per cent without damage. It is relatively insensitive to temperature change and measures either clockwise or counterclockwise torque. The use of semiconductors enhances signal discrimination at low output levels, making the torque transducer more effective than conventional strain gages.

2. Power Supply and Signal Conditioner

A combined transistorized power supply, bridge circuit, and amplifier provides a signal which is sent to the recorder. The unit is provided with a push button resistive circuit equivalent to a 125 inch-ounce torque and may be used to adjust the amplifier gain. By depressing the "R Cal" button on the unit a fixed signal of 125 inch-ounces is provided to the recorder. The gain of the amplifier is adjusted to a convenient reference (0.5 volts was used for all testing) and by adjusting the amplifier balance the full 0-0.5 volts travel of the recording pen is ensured.

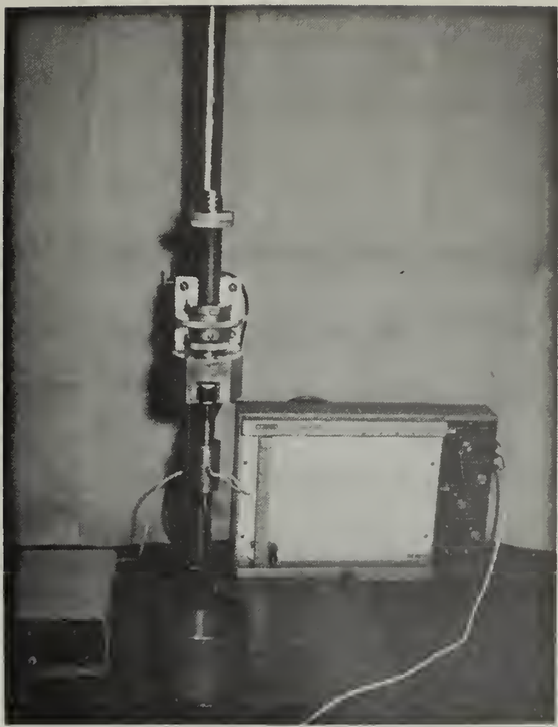
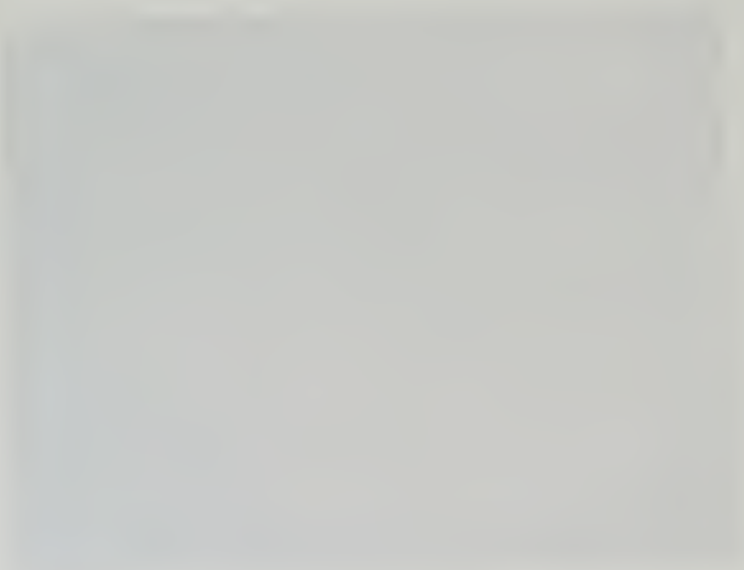


Figure 1.

NPS Vane Shear Apparatus with x-y Plotter

Figure 2. Five Revolutions Per Hour Motor and Motor Mount



3. Motor and Motor Mount

In addition to the motor and motor mount as devised by Minugh (one revolution per hour), five additional motors and one additional motor mount were obtained. The five motors were chosen to give higher rates of rotation of the vane. The speed of two revolutions per hour was chosen to verify Morelock's [1967] assumption that doubling the speed of rotation does not result in an erroneous value of shear strength. The values of five, ten, twenty, and thirty revolutions per hour were chosen as convenient multiples of the standard speed of one revolution per hour. Four of the additional motors were used in the existing motor mount and a second motor mount was constructed for the fifth, somewhat differently configured, motor (Figure 2). All six motors developed 150 inch-ounces of torque at 1 RPM and required 115 VAC, 60 cycle power. Five of the motors rotated in a counterclockwise direction while the sixth was reversible, but was only configured to rotate counterclockwise. The speeds of the motors used were:

Degrees per minute	RPM	RPH
6	1/60	1
12	1/30	2
30	1/12	5
60	1/6	10
120	1/3	20
180	1/2	30

[illegible]

For ease of reference all results are compared on the basis of revolutions per hour (RPH).

4. Vanes

A total of seven vanes, with from two to eight blades, were used. Standard vanes have four blades and varying H/D ratios. The range of two through eight blades allowed comparison of results with both fewer and greater number of blades than standard. A one-bladed vane was not used because of the imbalance of forces on the shaft of the vane. Eight blades was a practical upper limit from the standpoint of difficulty of fabrication. All the vanes had the same dimensions, a H/D ratio of two (H=2.0 inches, D=1.0 inches) and a shaft of 3/16 inches diameter. Figure 3 shows the seven vanes used.

5. Sample Containers

Two different sets of sample containers were prepared. The first set of seven containers varied in diameter from 1.611 inches to 10.298 inches. The second set of seven containers was essentially constant in size, with an average diameter of 4.992 inches. All containers were of a depth of 3.5 inches in order to allow 3/4 inches of sample above and below the vane during testing. Each container was fitted with two opposed slots at their base to ensure that they were securely held during the testing. Figures 4 and 5 show the containers. Packing the material to be tested into the containers required the preparation of the tamps shown in Figure 6. The various diameters of the containers were as follows:

Figure 3. Vanes with from Two to Eight Blades Used for Testing

Figure 4. Containers 1 through 7 Used for Testing

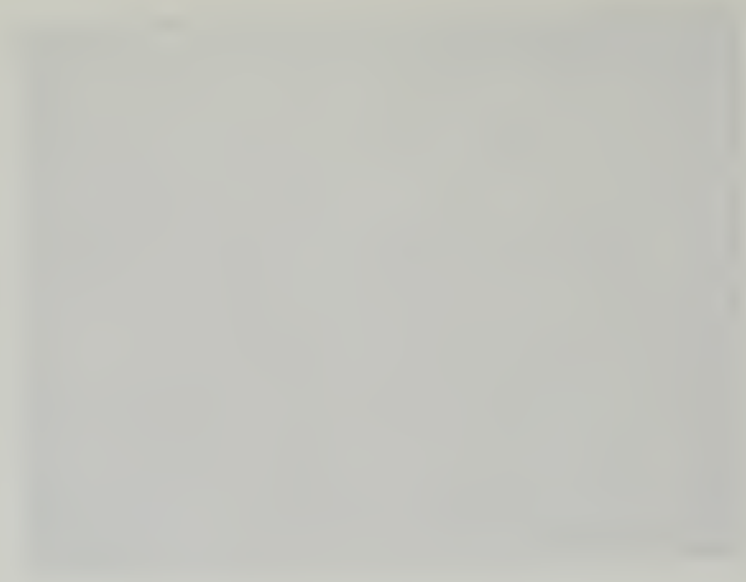


Figure 5. Containers A through G Used for Testing

Figure 6. Tamps for Containers 1 through 7 and A through G

Container	Internal Diameter (inches)
1	1.611
2	1.988
3	2.703
4	4.298
5	4.835
6	7.837
7	10.298
A through G	4.992 (average)

III. TESTING PROCEDURES

All tests were conducted during the months of January and February 1971 at the Naval Postgraduate School. The duration of the majority of tests was ten minutes. Exceptions were: (a) three minutes for motor speeds of five and ten revolutions per minute and (b) one and one half minutes for motor speeds of twenty and thirty revolutions per minute.

A. TEST MATERIALS

Marine sediments themselves are unsuitable for comparison testing of this type in that they continually lose water content and hence increase in shear strength in the drying process. Test materials were therefore required having strengths in the same range as marine sediments yet not subject to the evaporative process. The first material selected for testing was wheel bearing grease. In order to verify the results obtained, a type of sculpting clay was also selected. This clay did not have a water base and hence would not dry in air. Because the clay was originally much stronger than the wheel bearing grease, oil was added to the clay to bring it into the same range of shear strength as normal sediments. An electric hand drill with a paint mixer attachment was used to mix the clay and oil together to form a homogeneous test material.

B. PACKING THE CONTAINERS

The results of the vane shear tests proved difficult to reproduce with the grease, even when the same size container was used, due to non-uniform packing. A method of ensuring uniform packing was therefore necessary. The smaller containers had a tendency to entrap air resulting in values of shear strength which were lower than the actual values. A similar problem was encountered with the use of the clay.

Comparison of series of tests on the two sets of containers (1 through 7 and A through G) was more likely to yield usable results. The relative trends could therefore be compared. This was considered to be a practical approach to the testing because all the containers in the set were prepared nearly simultaneously and in the same manner.

A method was devised of placing the containers with the grease into a drying oven, in order to develop a greater degree of uniformity. Temperatures of 86 to 105 degrees Centigrade were used, with the majority of heating at the higher temperature. The containers were usually placed in the oven for at least six hours and then allowed to cool for more than ten hours. This procedure eliminated the air from the smaller containers, for at 105 degrees Centigrade the grease behaved as a thick liquid.

Because the clay might have hardened in the oven, tamps were prepared to fit within each of the containers. The tamps were used in conjunction with a clear plastic household wrapping material. The

plastic was used to keep the clay from adhering to the tamp. Great care had to be exercised to ensure that no air remained trapped in the smaller containers.

C. TEST PHASES

The temperature of the room in which testing was done was assumed to be essentially constant, in that it was located in the basement of a concrete building and thus not influenced by the heating of the sun. Both the grease and the oil and clay mixture were assumed to be homogeneous. To hold all but one test parameter constant, three test phases were used for each material.

1. Phase One

The first phase of testing required the motor speed and number of blades on the vane to be held constant while the diameter of the container was varied. A motor speed of 1 RPH and a four-bladed vane were used. Containers 1 through 7 were tested during this phase. For the testing of the clay container 5 was not used because it was close in size to container 4. Also, it was slightly out of round which made it difficult to pack.

2. Phase Two

Phase two involved the fixing of the container size and motor speed while varying the number of blades of the vanes. The essentially constant diameter containers A through G were used with a motor speed of 1 RPH. The vanes were varied from two to eight blades.

3. Phase Three

The third test phase used a constant container size and a fixed number of blades with a varied motor speed. The four-bladed vane, containers A through G, and motor speeds of 1, 2, 5, 10, 20, and 30 RPH were used.

IV. RESULTS OF TESTS

A. COMPUTATION OF SHEAR STRENGTH

From the shear strength formula of Cadling and Odenstad [1950]

$$S = \frac{M_{max}}{\left(\pi DH \frac{D}{2} + \frac{2\pi D^2}{4} \frac{2}{3} \frac{D}{2}\right)}$$

it can be seen that the denominator is a constant for the seven different vanes that were used. With H=2.0 inches and D=1.0 inches its value is 3.6652.

By setting the fixed 125 inch-ounces output of the amplifier equal to 0.5 volts the following relationship is established:

125 inch-ounces = 0.5 volts = 500 millivolts. Therefore

1 inch-ounce = 4 millivolts = 4 mv.

Since all values of M_{max} were obtained in millivolts, to compute shear strength in pounds per square inch (psi) the following factor was applied to the M_{max} in millivolts:

$$S\ (\text{psi}) = M_{max}\ (\text{mv}) \times \frac{1\ \text{in.-ounce}}{4\ \text{mv.}} \times \frac{1}{3.6652\ \text{in.}^3} \times \frac{1\ \text{pound}}{16\ \text{ounces}} .$$

Occassionally shear of the sample did not occur during the time allotted for the test. In these cases the maximum value of torque attained by the end of the test was used for computing the shear strength. Because the duration of each test was not varied, but fixed for particular motor

speeds, this was considered as a valid figure for comparison purposes. The results of the tests are given in Appendix A and are summarized in Tables I through VI.

Table I. Summary of Results of Phase One Tests Using Grease

Run No.	Speed (RPH)	No. of Blades	Container	Shear Strength (psi)
56	1	4	1	.364
57	"	"	2	.464
58	"	"	3	.334
59	"	"	4	.2245
60	"	"	5	.220
61	"	"	6	.1404
62	"	"	7	.151
63	1	4	1	.441
64	"	"	2	.340
65	"	"	3	.217
66	"	"	4	.3015
67	"	"	5	.288
68	"	"	6	.212
69	"	"	7	.2045
70	1	4	1	.2565
71	"	"	2	.218
72	"	"	3	.216
73	"	"	4	.2345
74	"	"	5	.207
75	"	"	6	.198
76	"	"	7	.2457
77	1	4	1	.294
78	"	"	2	.319
79	"	"	3	.268
80	"	"	4	.1947
81	"	"	5	.2715
82	"	"	6	.2215
83	"	"	7	.258
84	1	4	1	.264
85	"	"	2	.287
86	"	"	3	.2255
87	"	"	4	.2235
88	"	"	5	.250
89	"	"	6	.2325
90	"	"	7	.1988

Run No.	Speed (RPH)	No. of Blades	Container	Shear Strength (psi)
91	1	4	1	.286
92	"	"	2	.264
93	"	"	3	.231
94	"	"	4	.2295
95	"	"	5	.242
96	"	"	6	.206
97	"	"	7	.197
98	1	4	1	.302
99	"	"	2	.306
100	"	"	3	.2765
101	"	"	4	.2063
102	"	"	5	.2115
103	"	"	6	.2283
104	"	"	7	.2182

Table II. Summary of Results of Phase One Tests Using Clay

Run No.	Speed (RPH)	No. of Blades	Container	Shear Strength (psi)
170	1	4	1	.2217
171	"	"	2	.195
172	"	"	3	.183
173	"	"	4	.160
180	1	4	1	.206
181	"	"	2	.2383
182	"	"	3	.2742
183	"	"	4	.2313
184	"	"	6	.1867
185	"	"	7	.180
222	1	4	1	.305
221	"	"	2	.268
220	"	"	3	.2593
219	"	"	4	.2183
218	"	"	6	.2015
217	"	"	7	.1818

Table III. Summary of Results of Phase Two Tests Using Grease

Run No.	Speed (RPH)	No. of Blades	Container	Shear Strength (psi)
105	1	2	A	.226
106	"	3	B	.297
107	"	4	C	.2975
108	"	5	D	.2767
109	"	6	E	.2467
110	"	7	F	.3275
111	"	8	G	.2165
112	1	2	A	.2515
113	"	3	B	.2465
114	"	4	C	.300
115	"	5	D	.293
116	"	6	E	.294
117	"	7	F	.386
118	"	8	G	.285
119	1	2	A	.2235
120	"	3	B	.2403
121	"	4	C	.280
122	"	5	D	.272
123	"	6	E	.2335
124	"	7	F	.334
125	"	8	G	.2597
126	1	2	A	.2155
127	"	3	B	.227
128	"	4	C	.248
129	"	5	D	.240
130	"	6	E	.2495
131	"	7	F	.281
132	"	8	G	.2617
156	1	2	A	.2745
157	"	3	B	.2896
158	"	4	C	.247
159	"	5	D	.2675
160	"	6	E	.264
161	"	7	F	.2995

Table IV. Summary of Results of Phase Two Tests Using Clay

Run No.	Speed (RPH)	No. of Blades	Container	Shear Strength (psi)
189	1	2	A	.176
190	"	3	B	.1985
191	"	4	C	.208
192	"	5	D	.242
193	"	6	E	.2173
194	"	7	F	.213
195	"	8	G	.215
203	1	2	A	.166
204	"	3	B	.238
205	"	4	C	.220
206	"	5	D	.2173
207	"	6	E	.237
208	"	7	F	.242
209	"	8	G	.2295

Table V. Summary of Results of Phase Three Tests Using Grease

Run No.	Speed (RPH)	No. of Blades	Container	Shear Strength (psi)
133	1	4	A	.2735
134	2	"	B	.279
135	5	"	C	.279
136	10	"	D	.3215
137	20	"	E	.400
138	30	"	F	.429
144	1	4	A	.222
145	2	"	B	.2185
146	5	"	C	.2755
147	10	"	D	.329
148	20	"	E	.3405
149	30	"	F	.380
174	1	4	A	.284
175	2	"	B	.274
176	5	"	C	.294
177	10	"	D	.3935
178	20	"	E	.432
179	30	"	F	.3493

Table VI. Summary of Results of Phase Three Tests Using Clay

Run No.	Speed (RPH)	No. of Blades	Container	Shear Strength (psi)
196	1	4	A	.2268
197	2	"	B	.2259
198	5	"	C	.266
199	10	"	D	.3245
200	20	"	E	.2595
201	30	"	F	.281
211	1	4	B	.2295
212	2	"	C	.2355
213	5	"	D	.2723
214	10	"	E	.3405
215	20	"	F	.364
216	30	"	G	.3313

B. RESULTS

1. Phase One

Tables I and II summarize the results of phase one tests in which the motor speed and number of blades were held constant while the container diameter was varied. Figures 7 through 16 show the plots of shear strength versus container diameter. Five of the ten series of tests conducted during this phase showed an increase in shear strength from container 1 to container 2 along with subsequent isolated instances of increase. The overall tendency was, however, for shear strength to decrease with increasing container size. Figure 12 for the grease and Figure 16 for the clay are representative of the relative decrease in shear strengths. The solid line in Figure 12 is based on the discounting of the value of shear strength for container 5. Figure 14 shows only four points because a sufficient quantity of clay to fill all the containers had not been mixed when the testing of the clay was started.

2. Phase Two

The results of the phase two tests are summarized in Tables III and IV. In this phase the number of blades was varied while the container diameter and motor speed were held constant. Figures 17 through 23 show the plots of shear strength versus number of blades. The vane with seven blades gave results which were generally too high. This was apparently caused by a slight eccentricity in the rotation of the vane. The results of the seven-bladed vane were thus

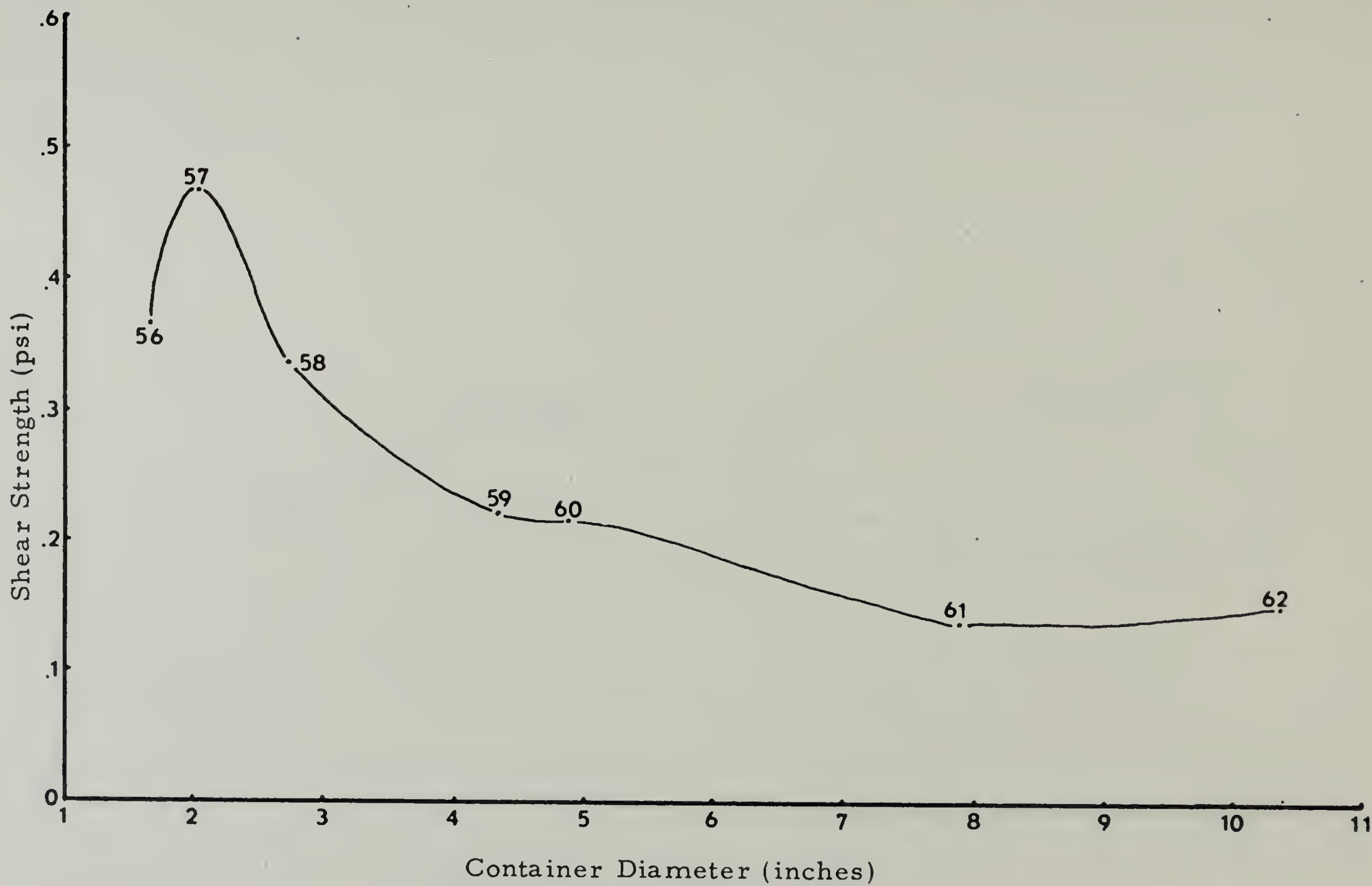


Figure 7. Shear Strength versus Container Diameter, Runs 56-62, Grease

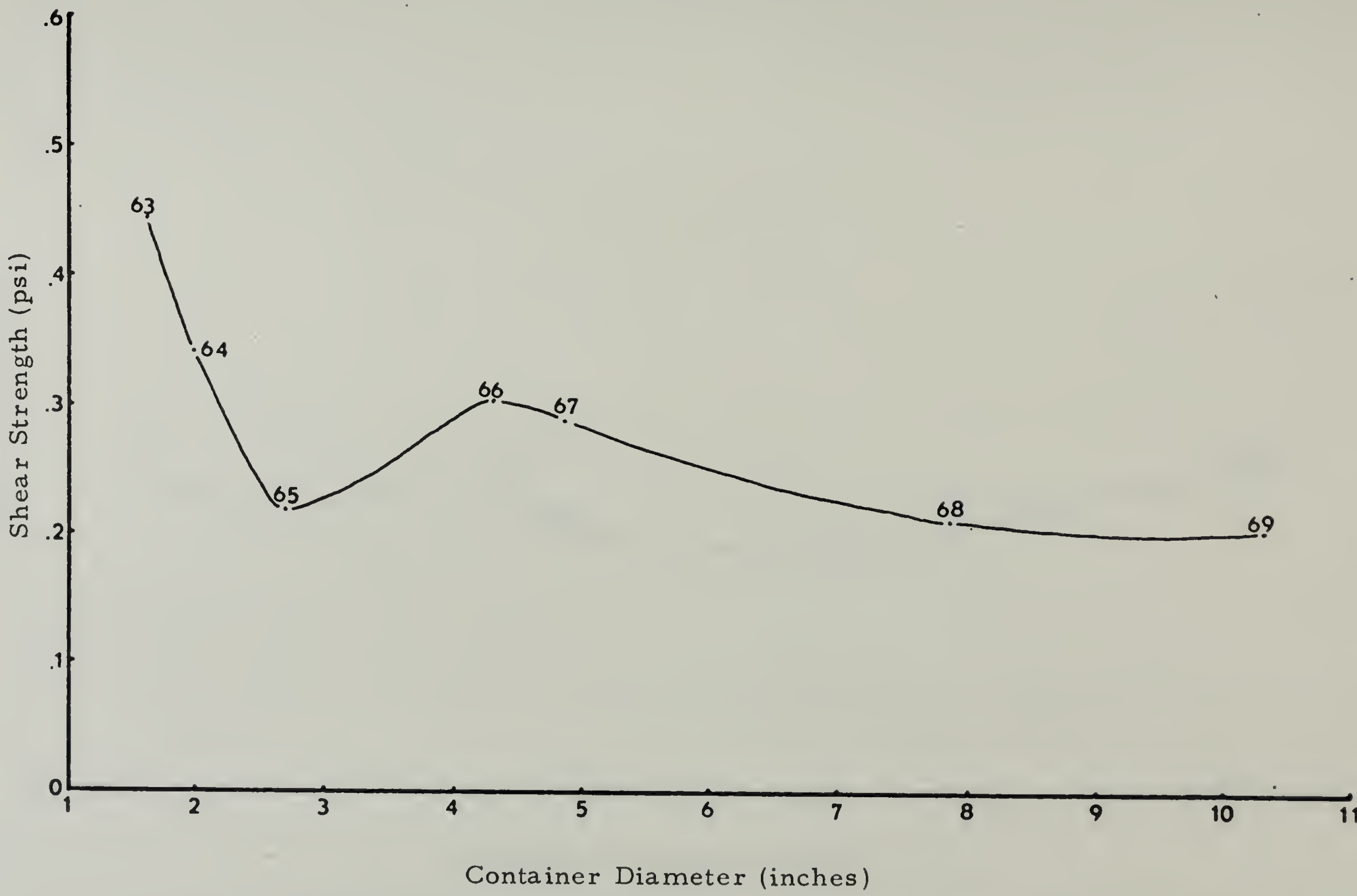


Figure 8. Shear Strength versus Container Diameter, Runs 63-69, Grease

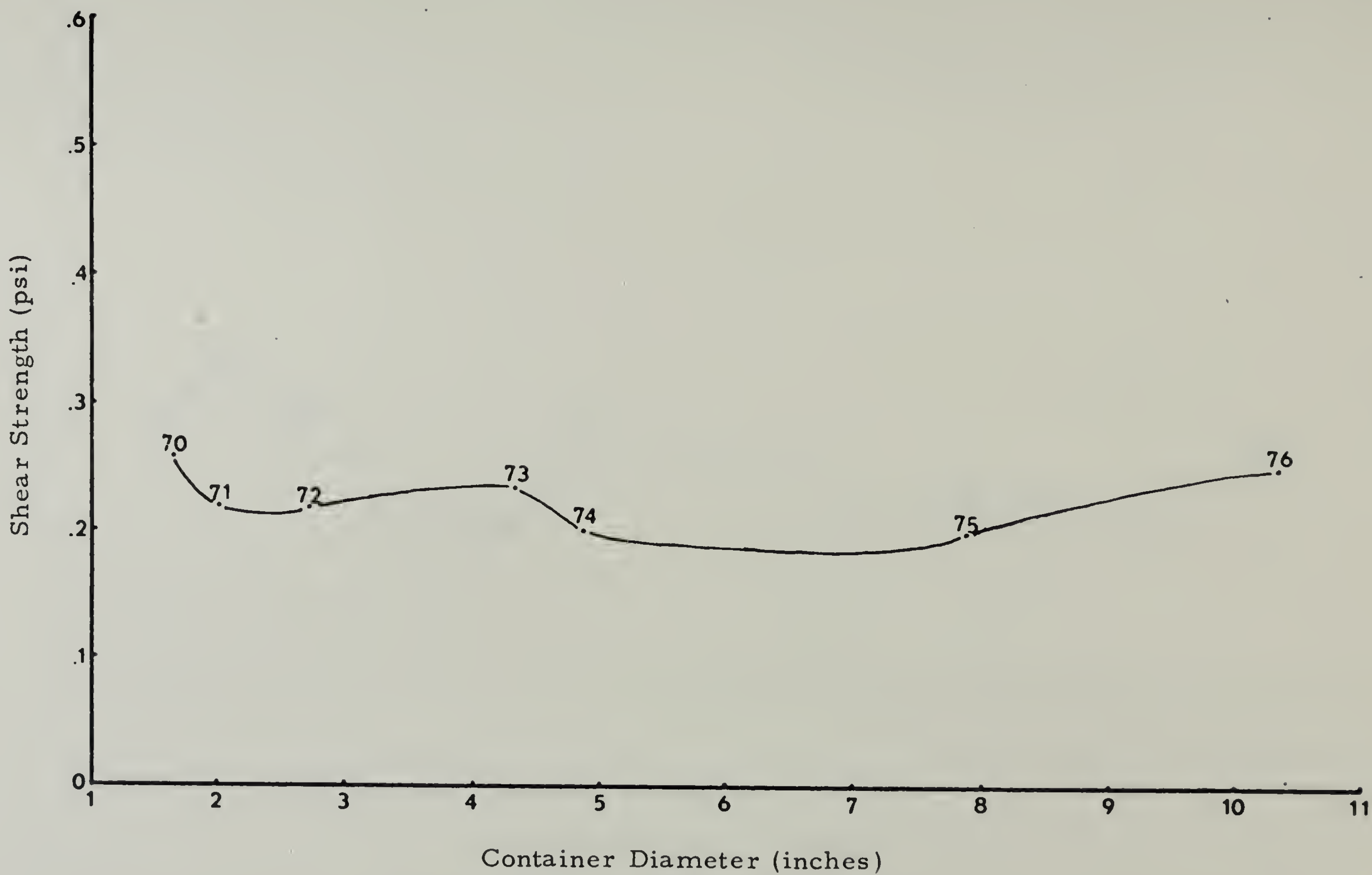


Figure 9. Shear Strength versus Container Diameter, Runs 70-76, Grease

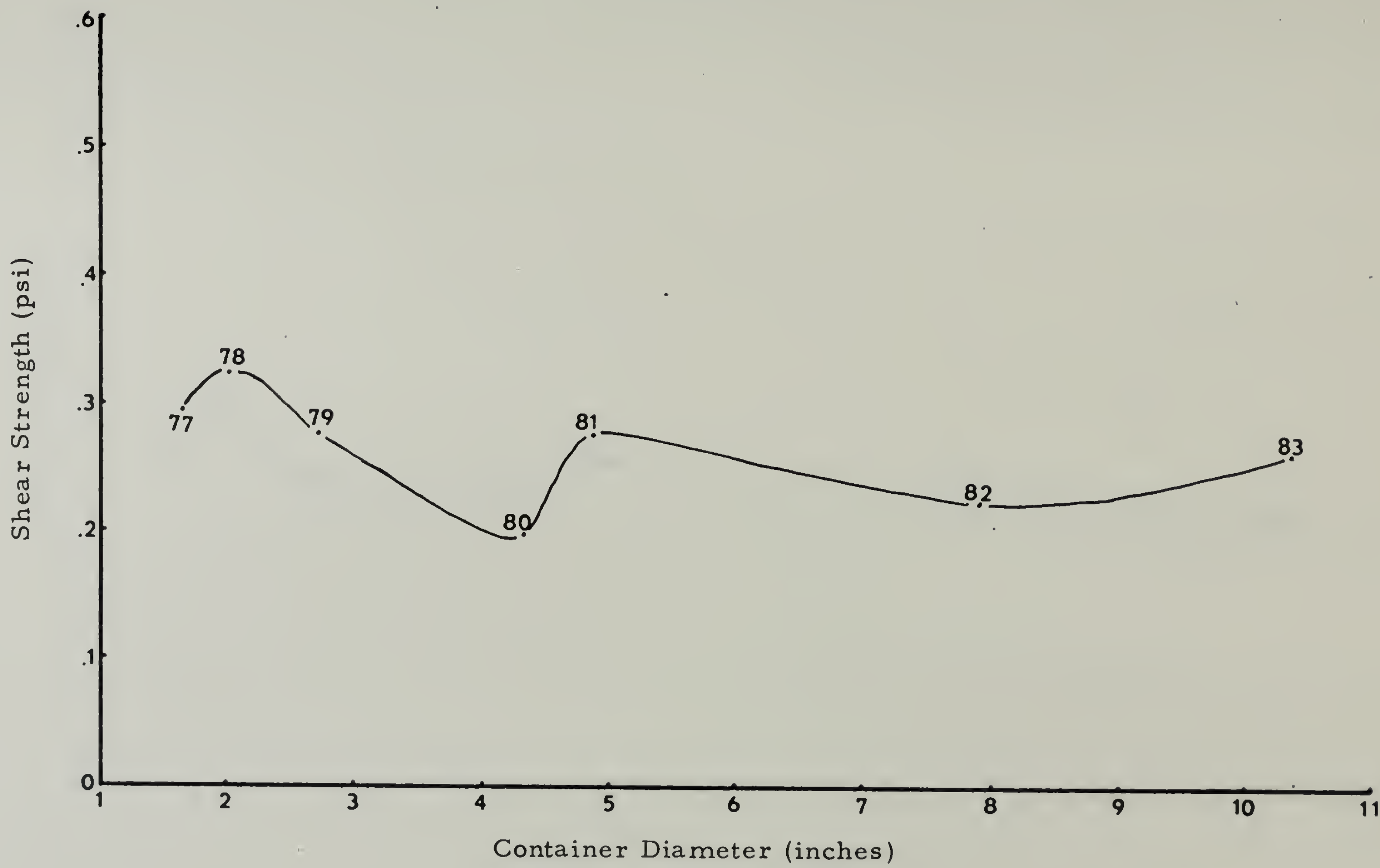


Figure 10. Shear Strength versus Container Diameter, Runs 77-83, Grease

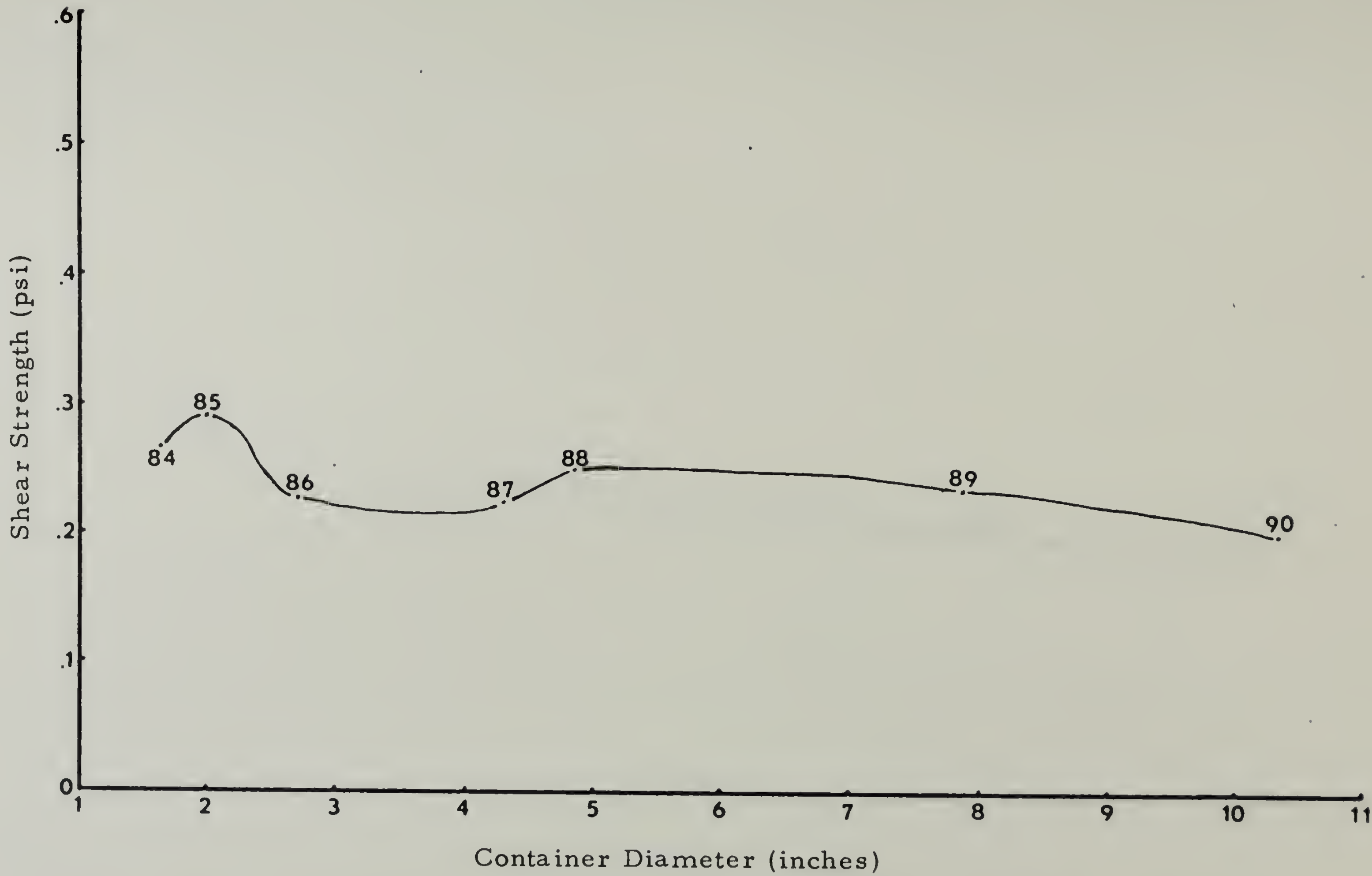


Figure 11. Shear Strength versus Container Diameter, Runs 84-90, Grease

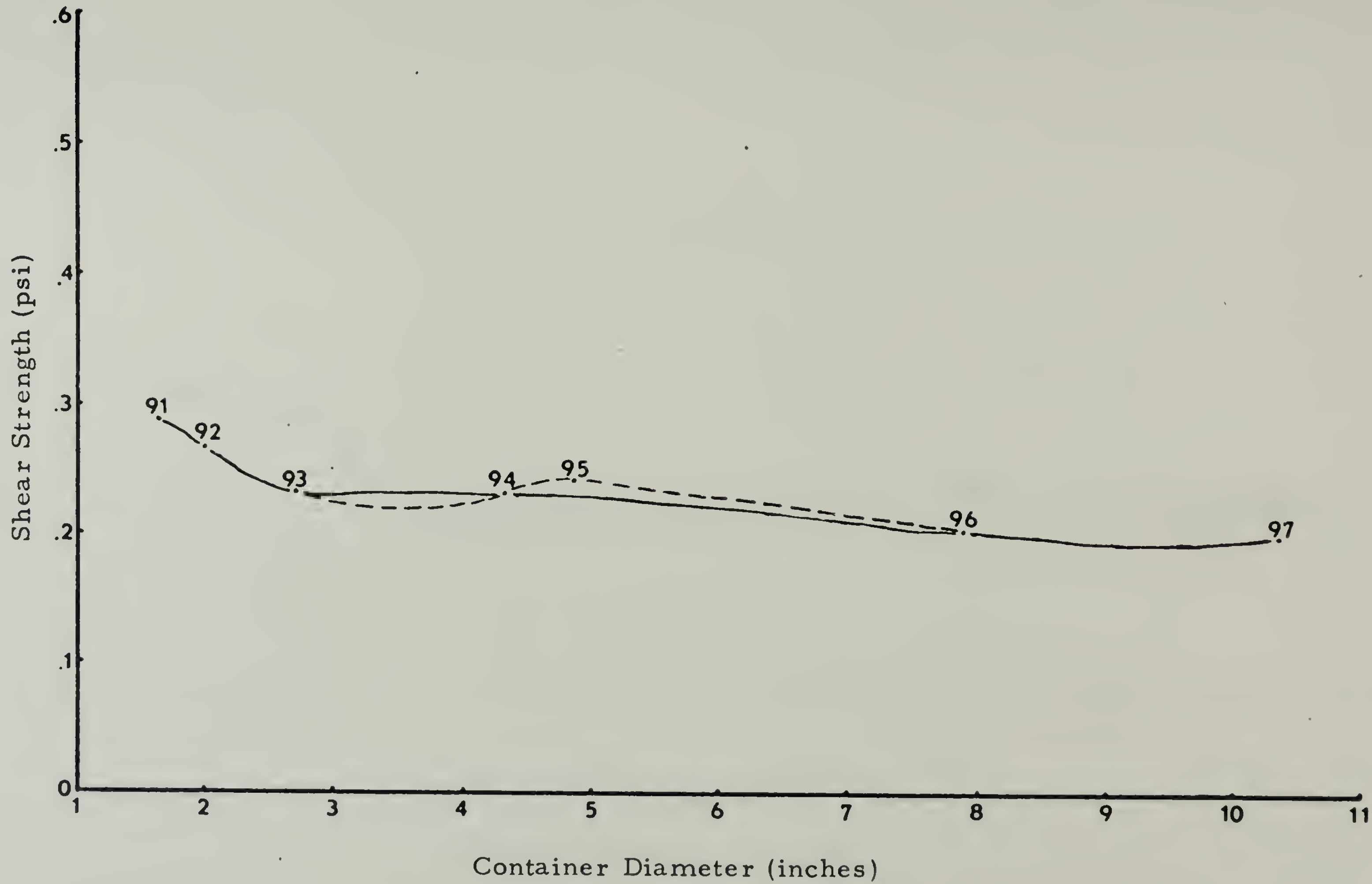


Figure 12. Shear Strength versus Container Diameter, Runs 91-97, Grease

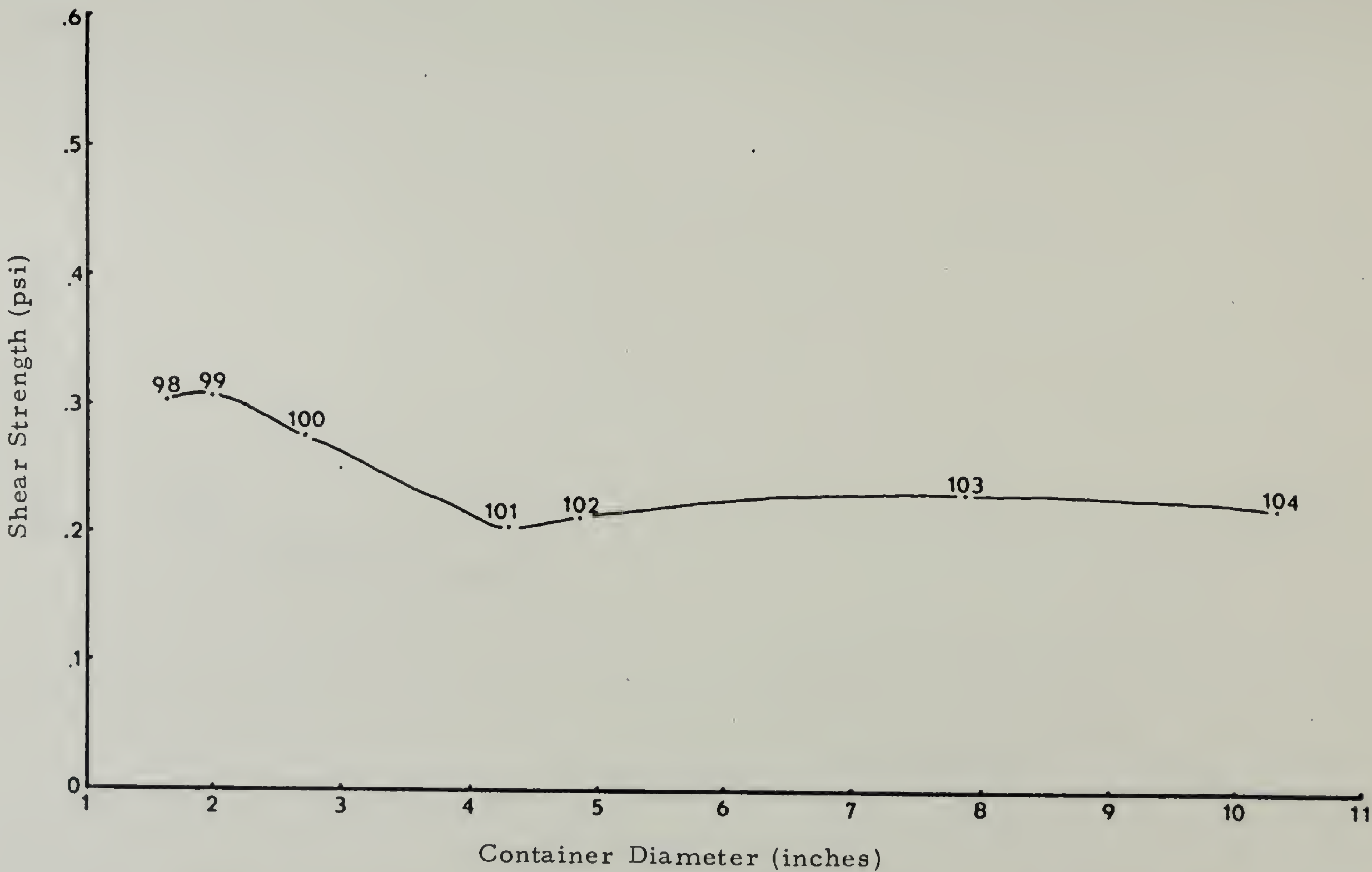


Figure 13. Shear Strength versus Container Diameter, Runs 98-104, Grease

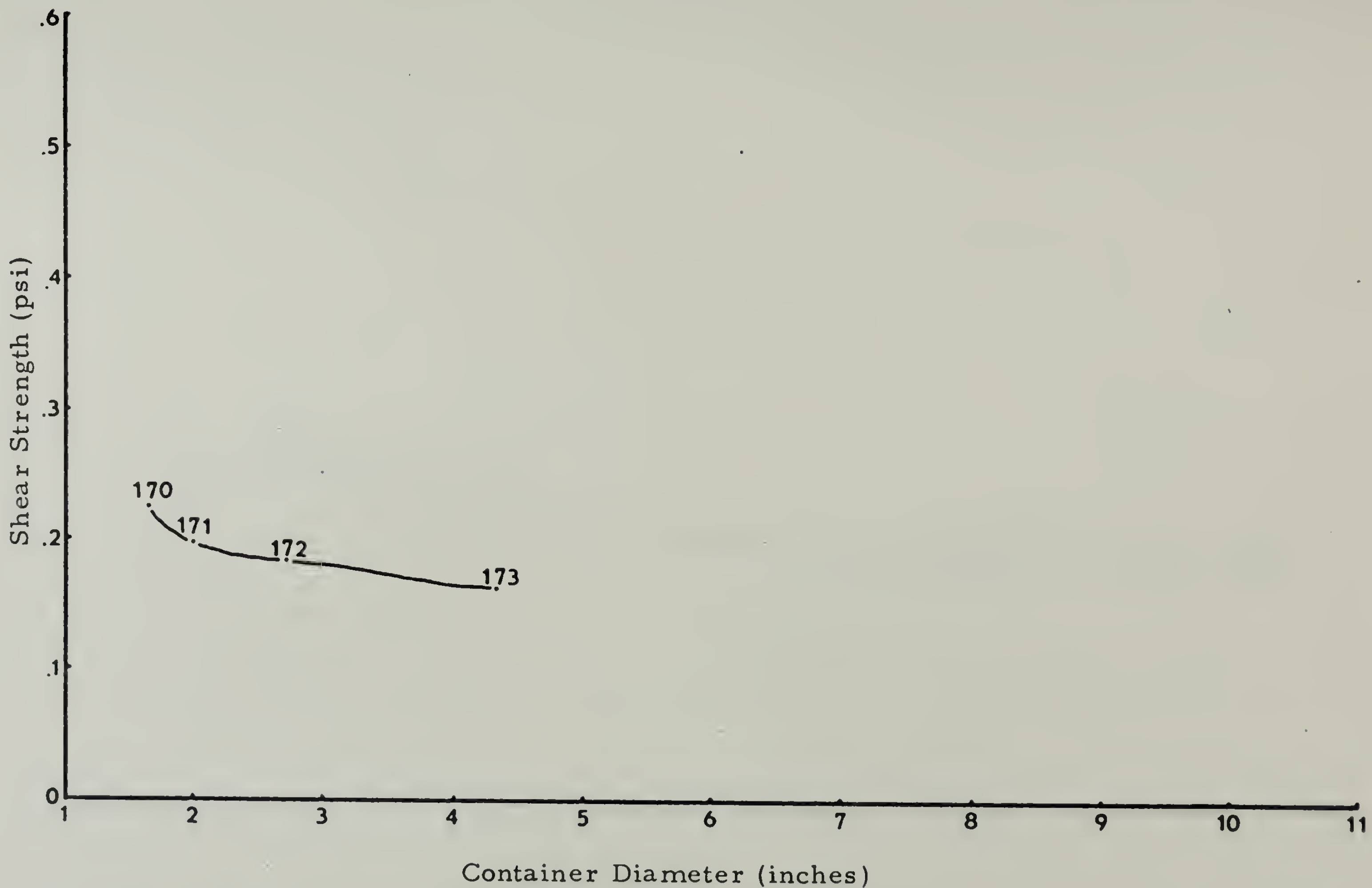


Figure 14. Shear Strength versus Container Diameter, Runs 170-173, Clay

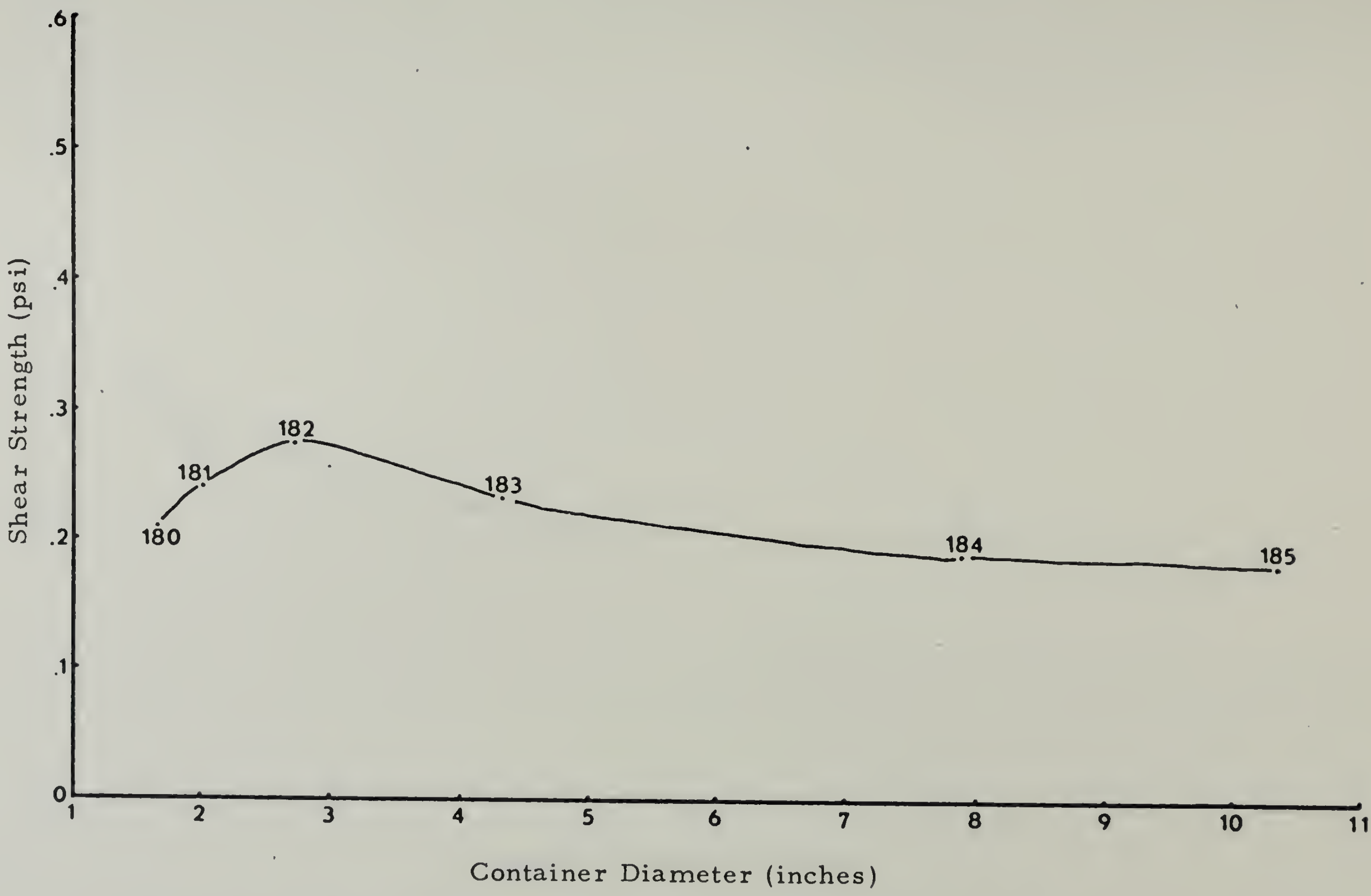


Figure 15. Shear Strength versus Container Diameter, Runs 180-185, Clay

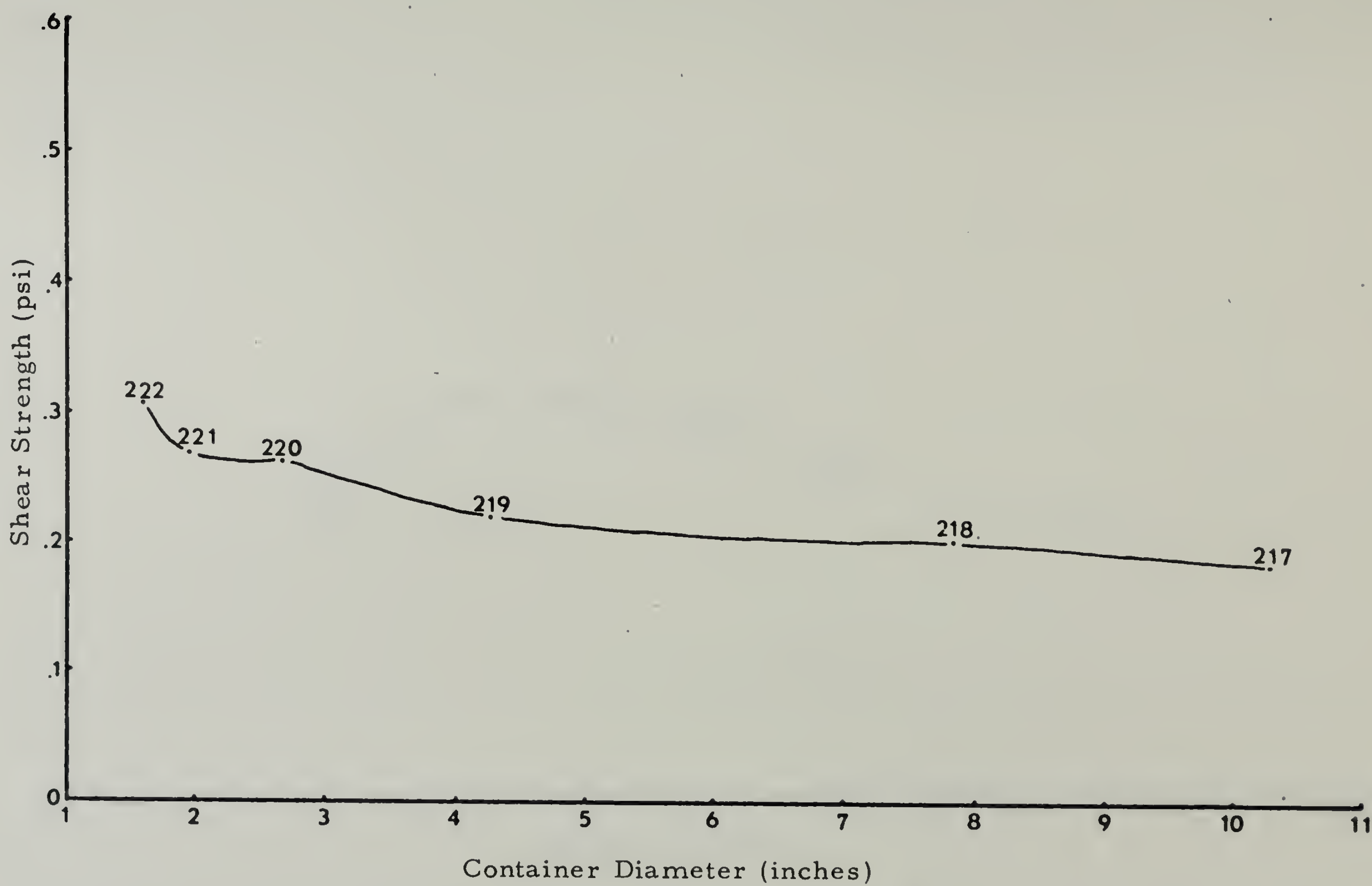


Figure 16. Shear Strength versus Container Diameter, Runs 217-222, Clay

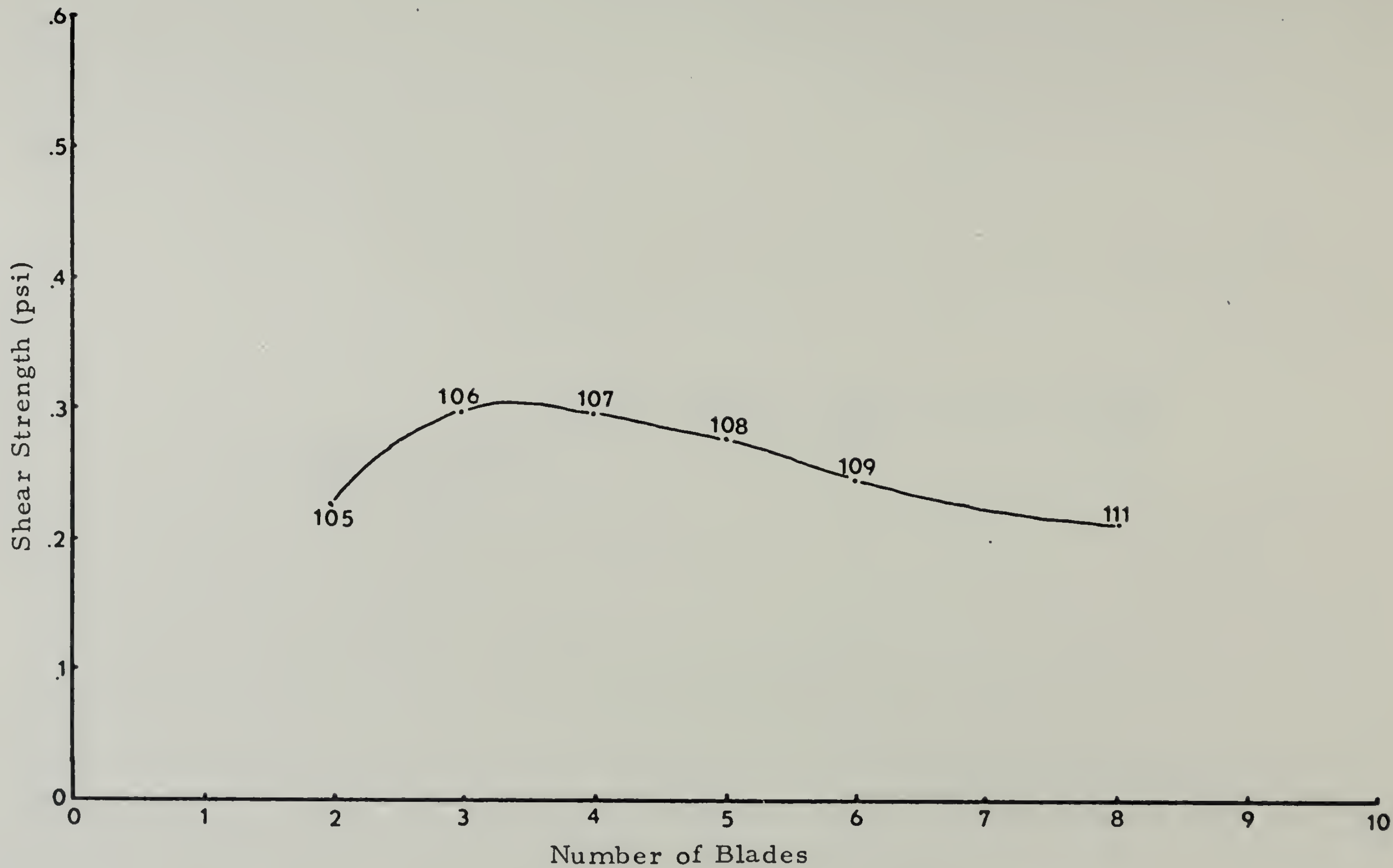


Figure 17. Shear Strength versus Number of Blades, Runs 105-111, Grease

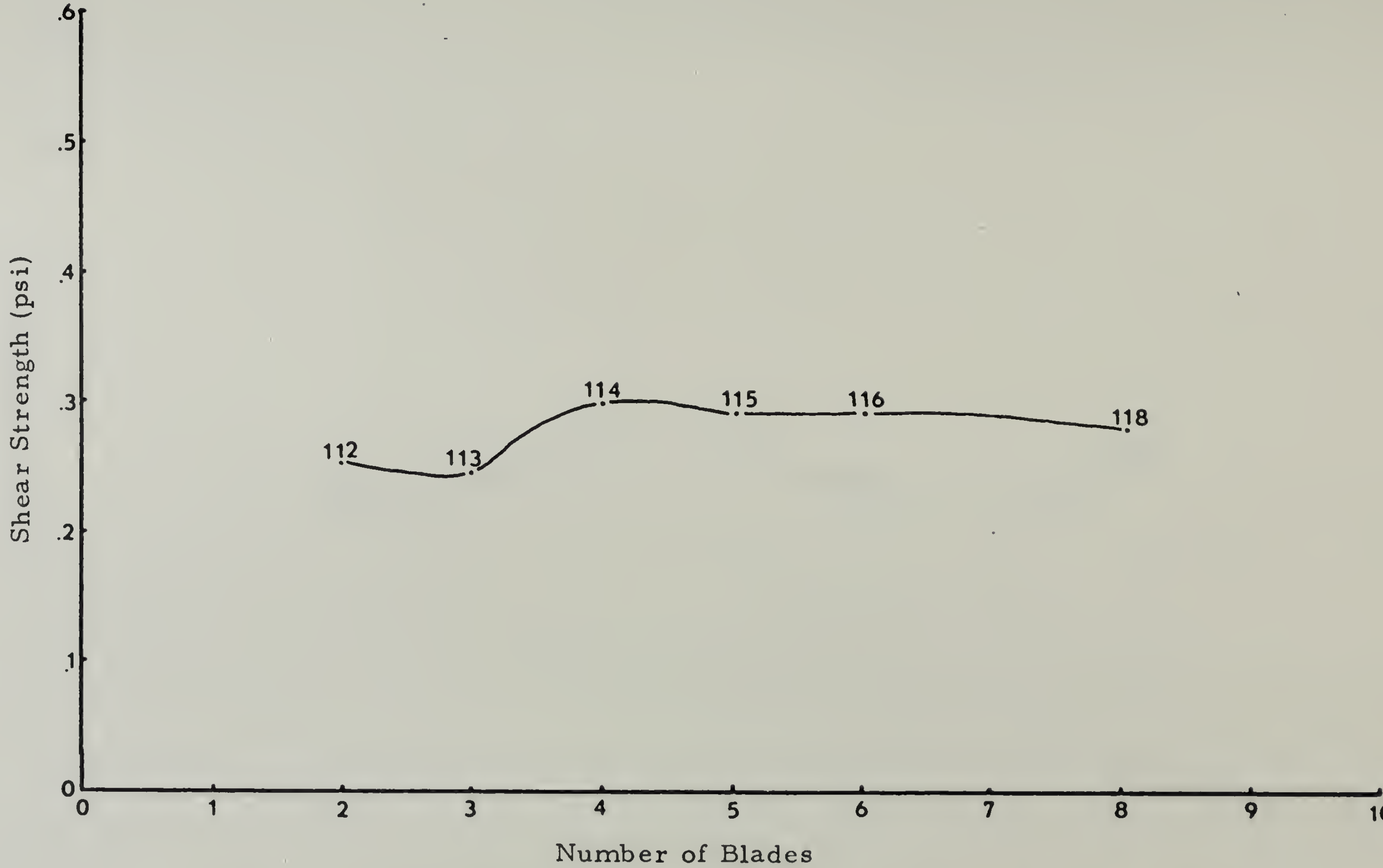
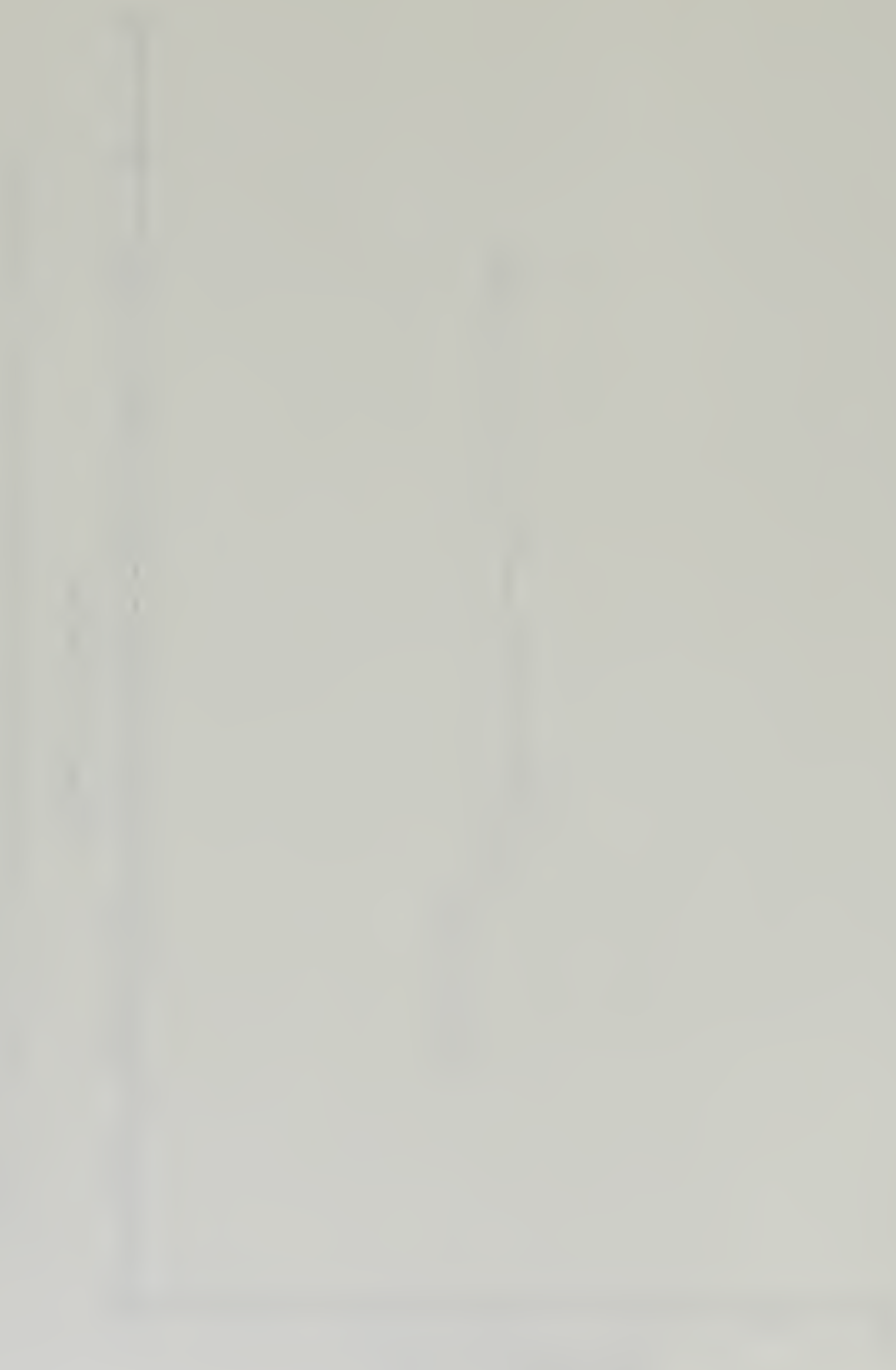


Figure 18. Shear Strength versus Number of Blades, Runs 112-118, Grease



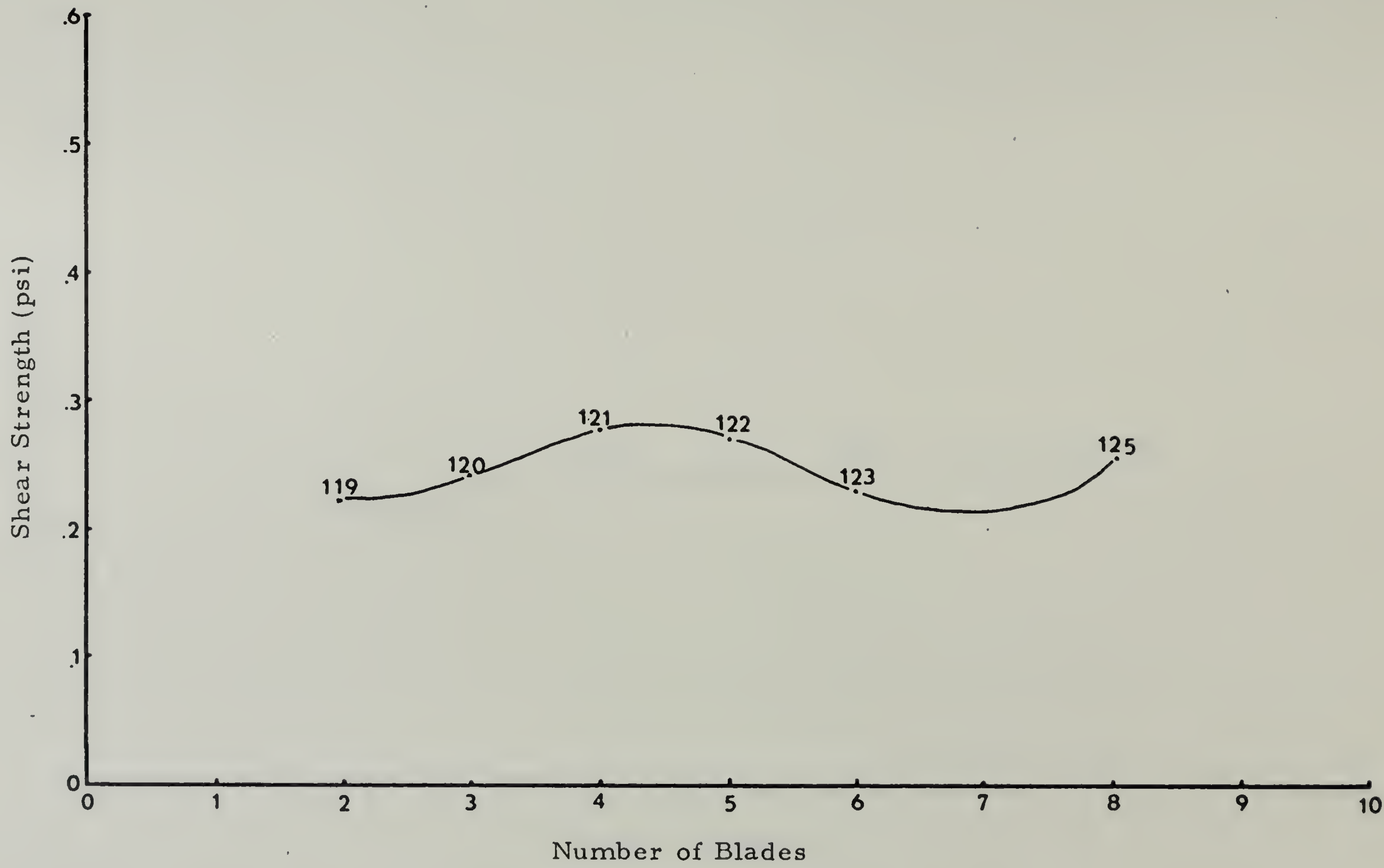


Figure 19. Shear Strength versus Number of Blades, Runs 119-125, Grease

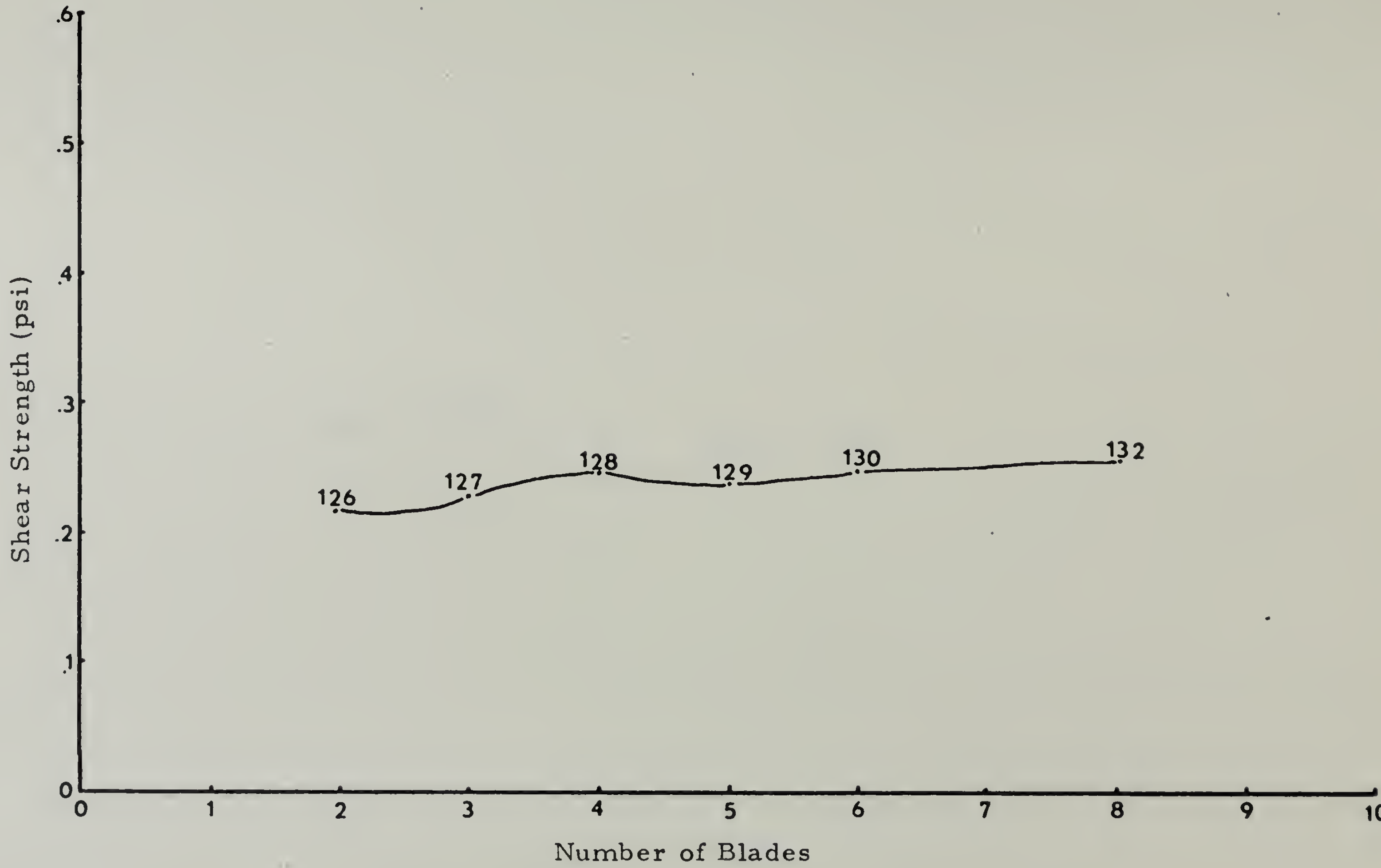


Figure 20. Shear Strength versus Number of Blades, Runs 126-132, Grease

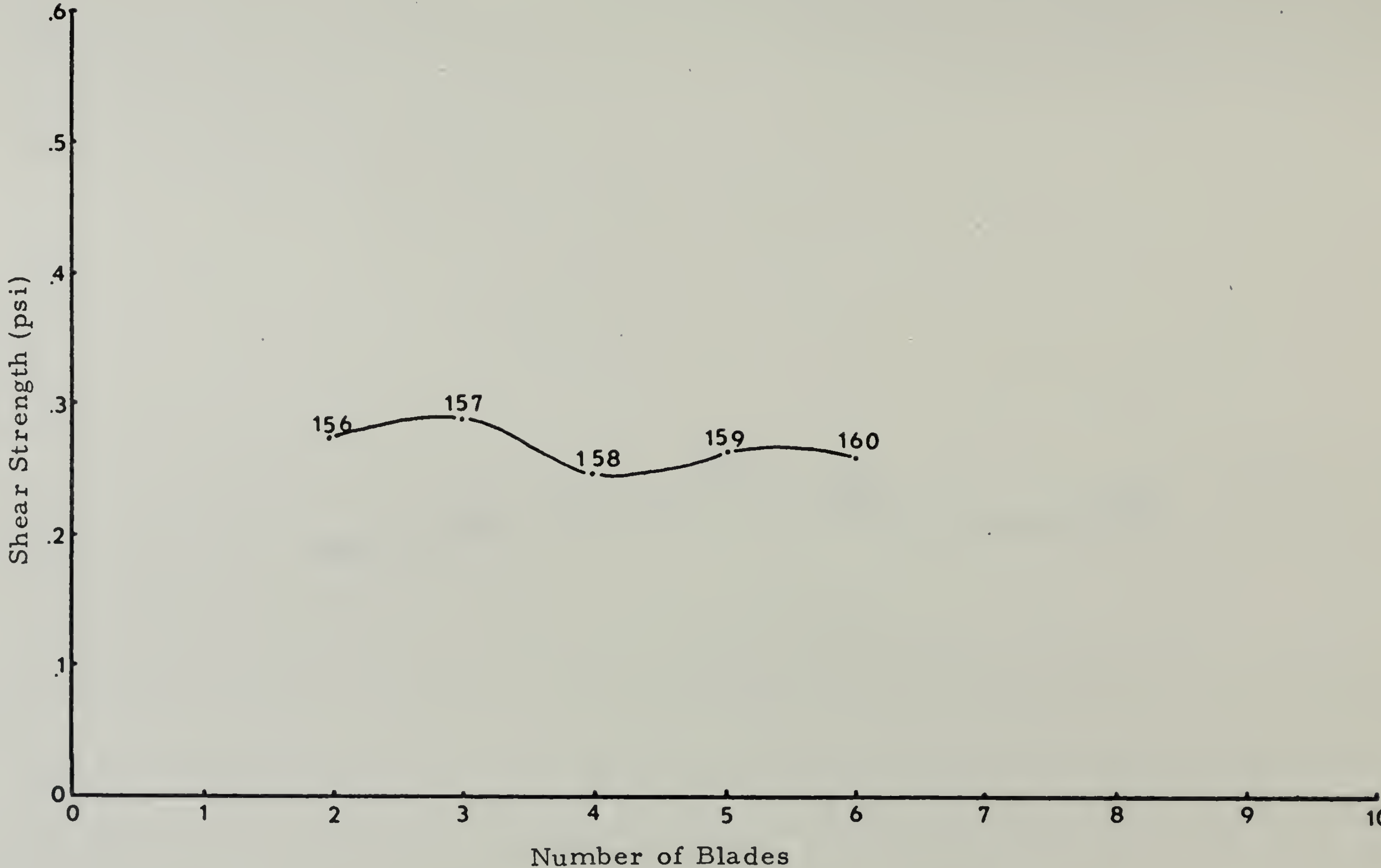


Figure 21. Shear Strength versus Number of Blades, Runs 156-160, Grease

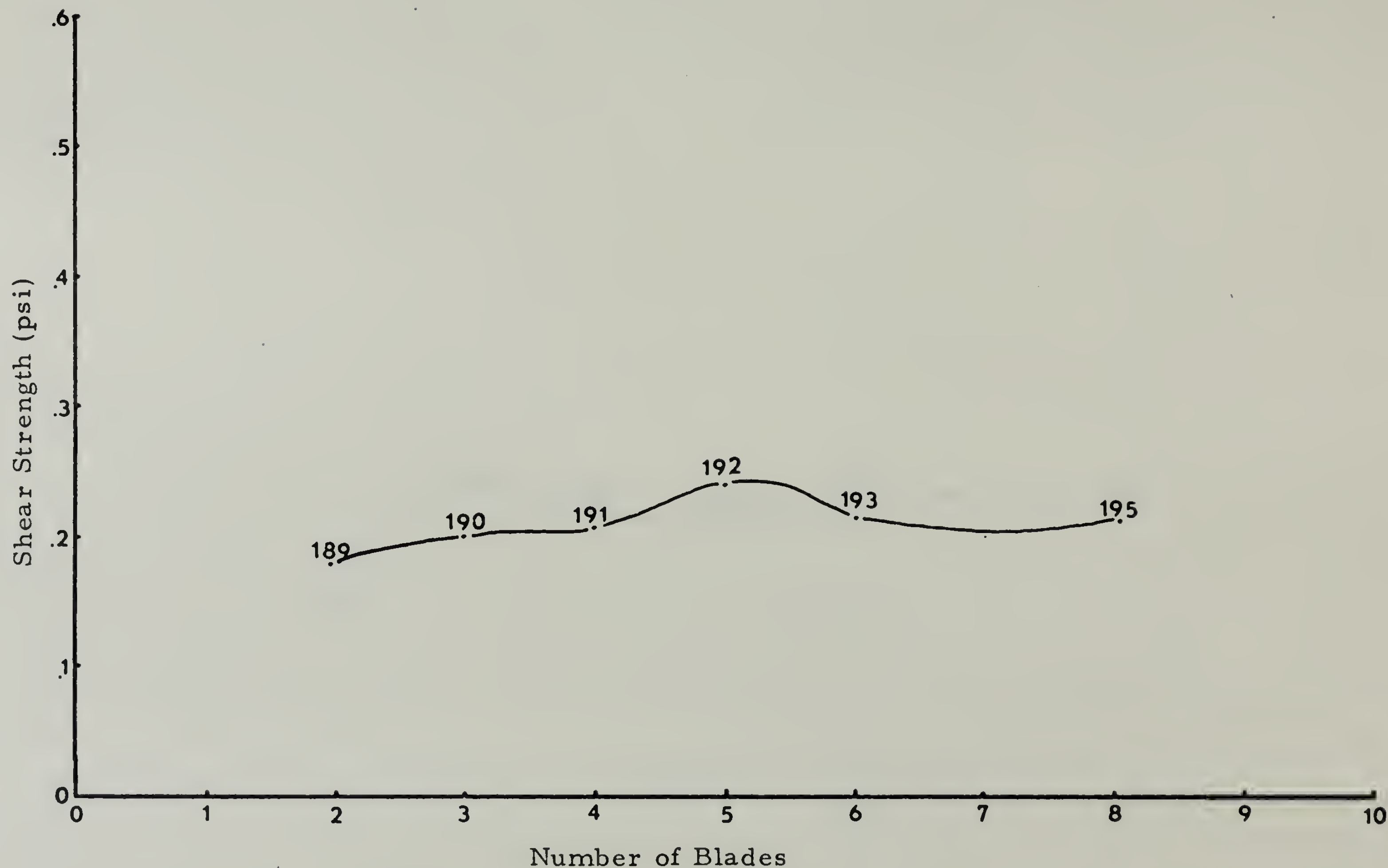
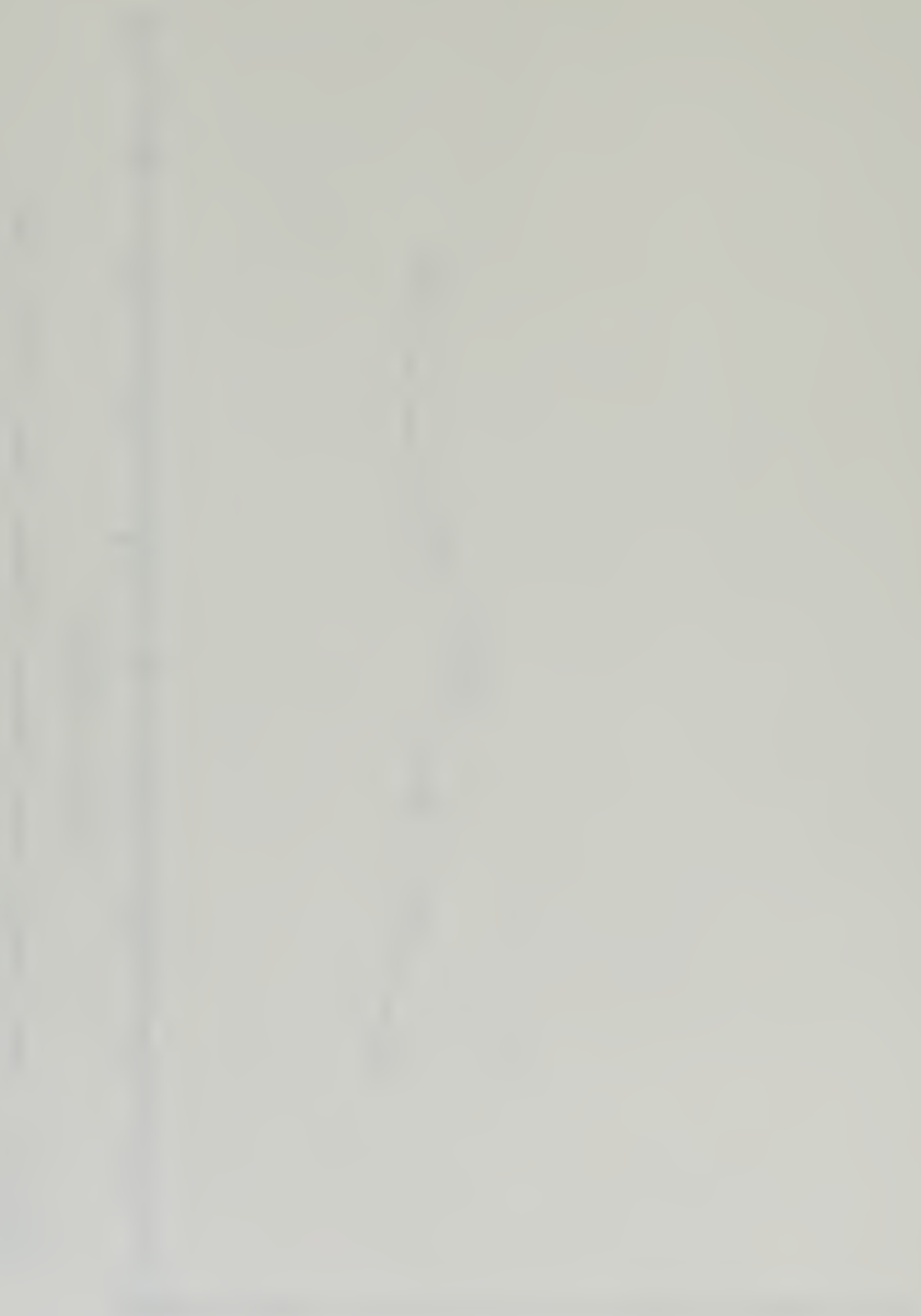


Figure 22. Shear Strength versus Number of Blades, Runs 189-195, Clay



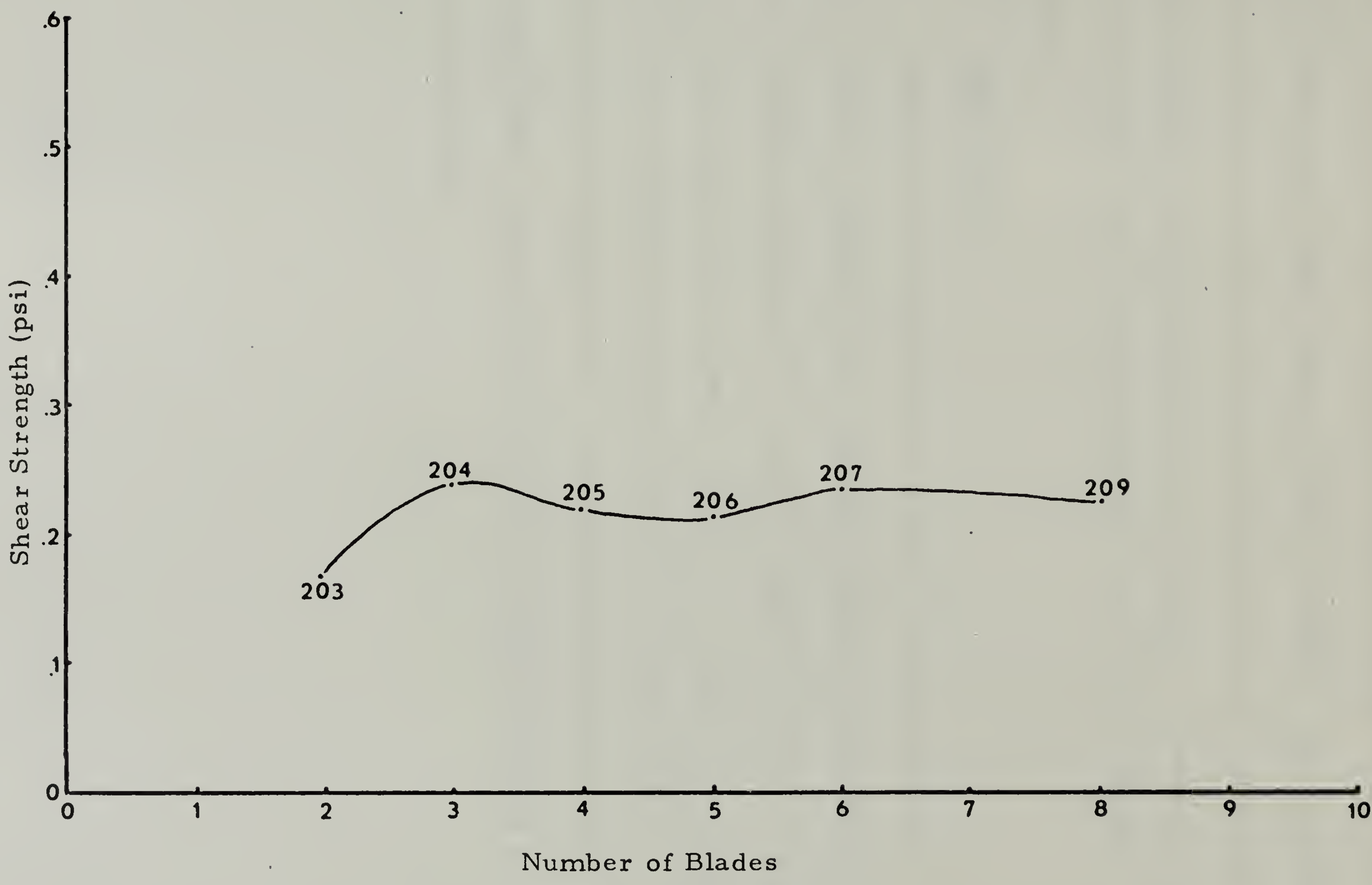


Figure 23. Shear Strength versus Number of Blades, Runs 203-209, Clay

discounted. All the plots of shear strength versus number of blades showed a maximum in the range of three to five blades. Vanes with over five blades gave lower values of shear strength. This is believed to be caused by the increased amount of disturbance near the shaft of the vane when the vane was inserted into the sample. The larger hole left in the sample after removal of the vanes served to verify this conclusion.

3. Phase Three

Summarized results of tests of phase three are given in Tables V and VI. In phase three container diameter and number of blades were held constant while the motor speed was varied. Plots of shear strength versus motor speed are shown in Figures 24 through 28. Shear strength generally increased with increased motor speed. The values of shear strength for the 1 and 2 RPH speeds were in close agreement with a definite increase in shear strength occurring at speeds above 2 RPH.

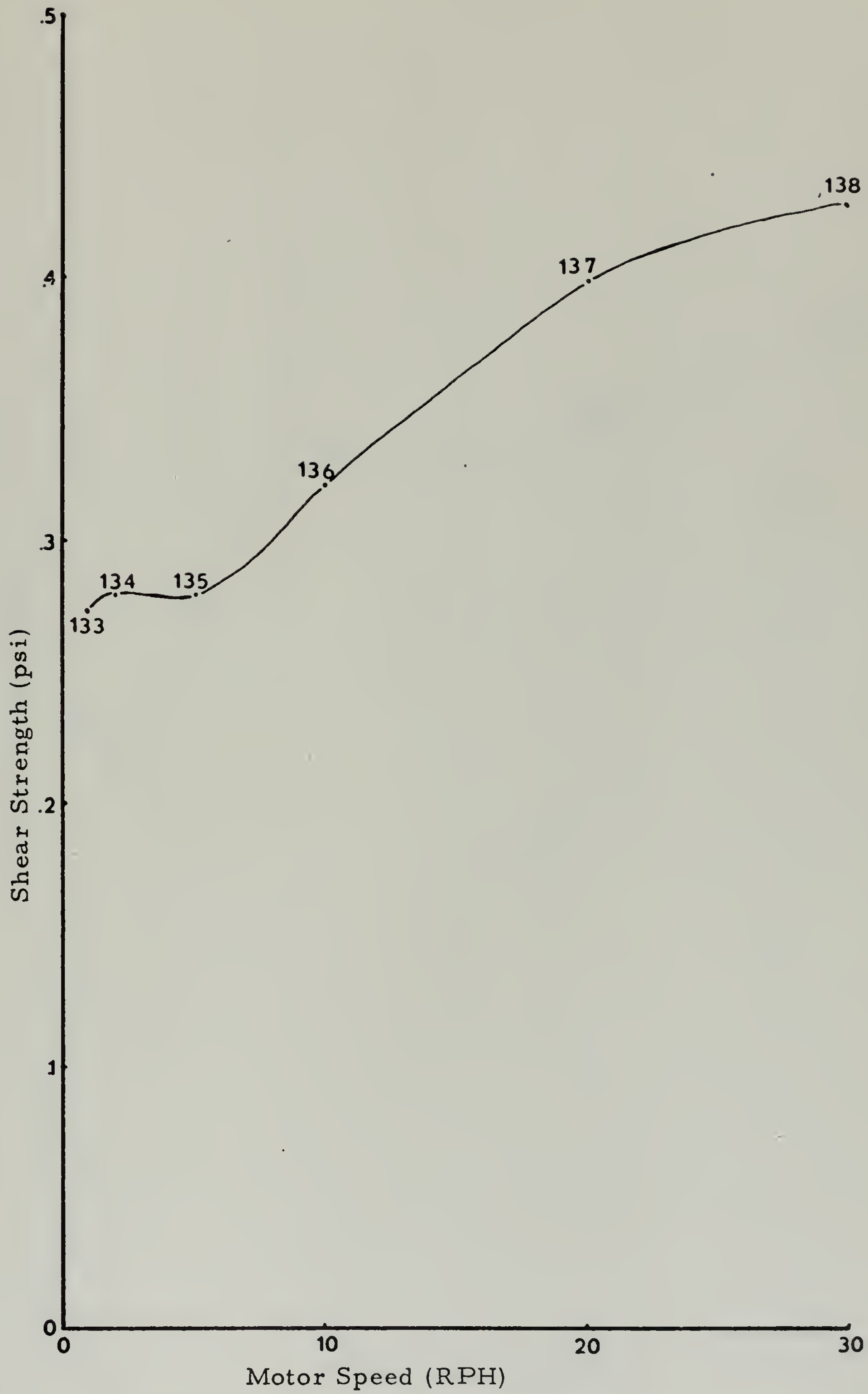


Figure 24. Shear Strength versus Motor Speed, Runs 133-138, Grease

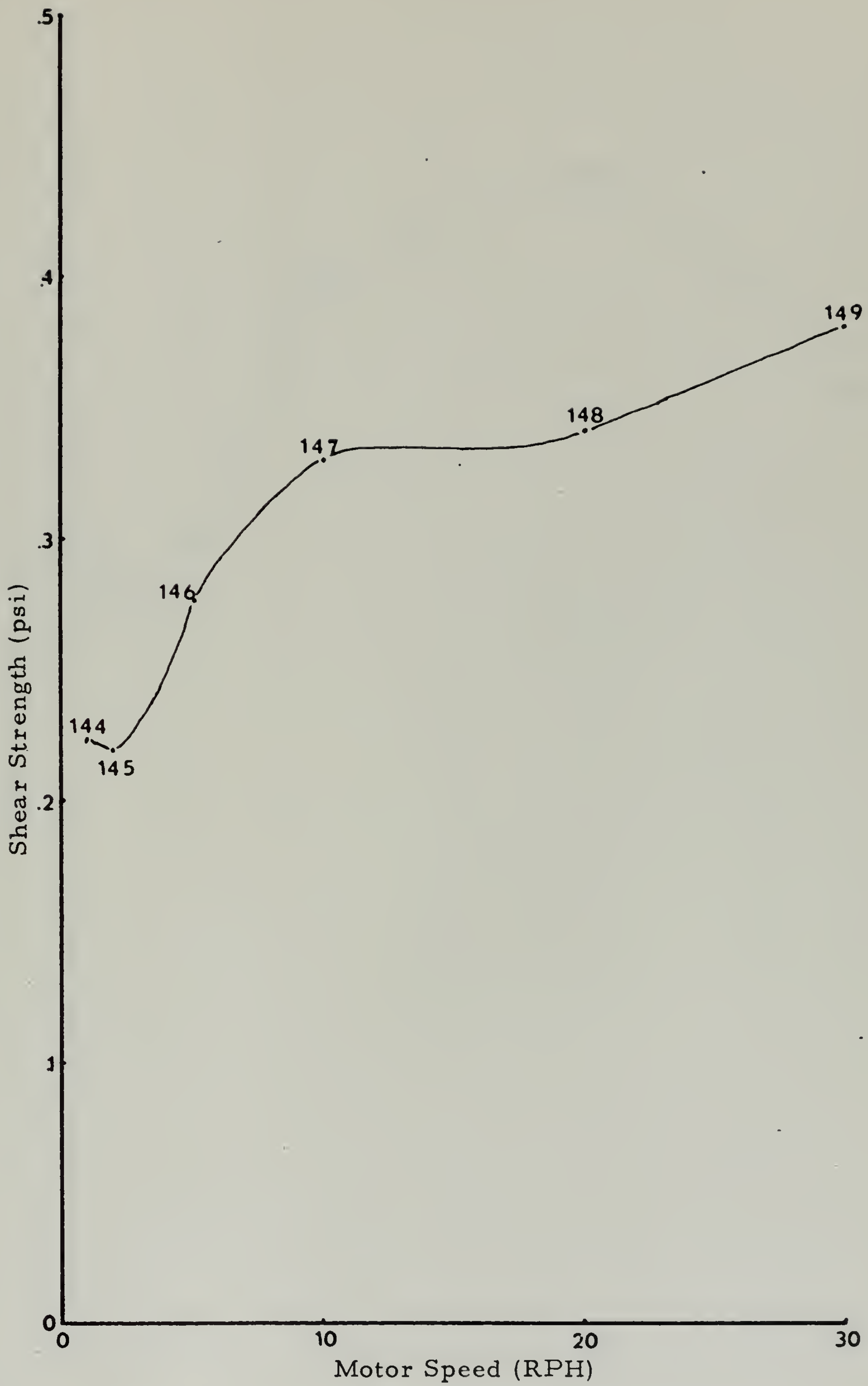


Figure 25. Shear Strength versus Motor Speed, Runs 144-149, Grease

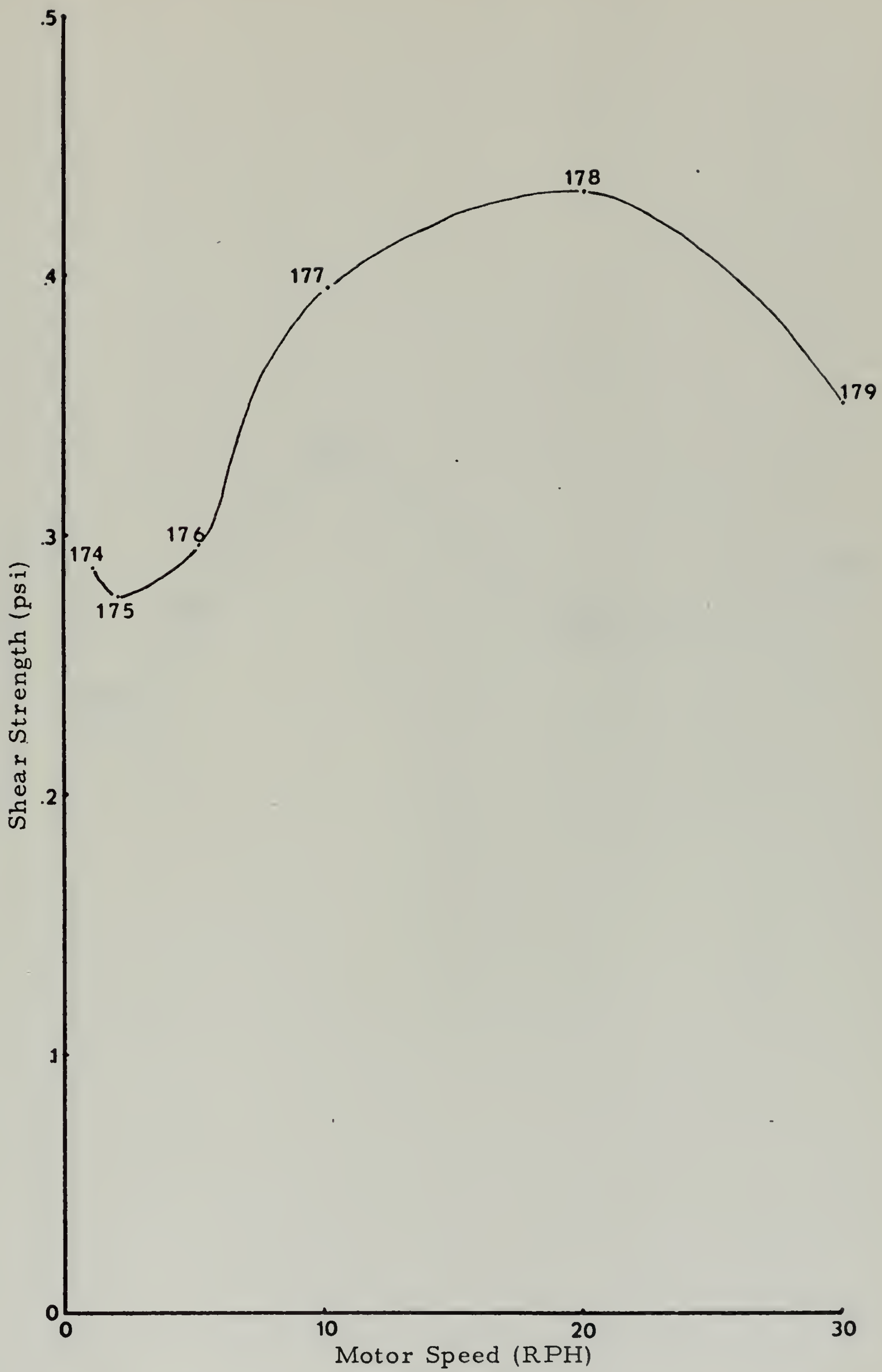


Figure 26. Shear Strength versus Motor Speed, Runs 174-179, Grease

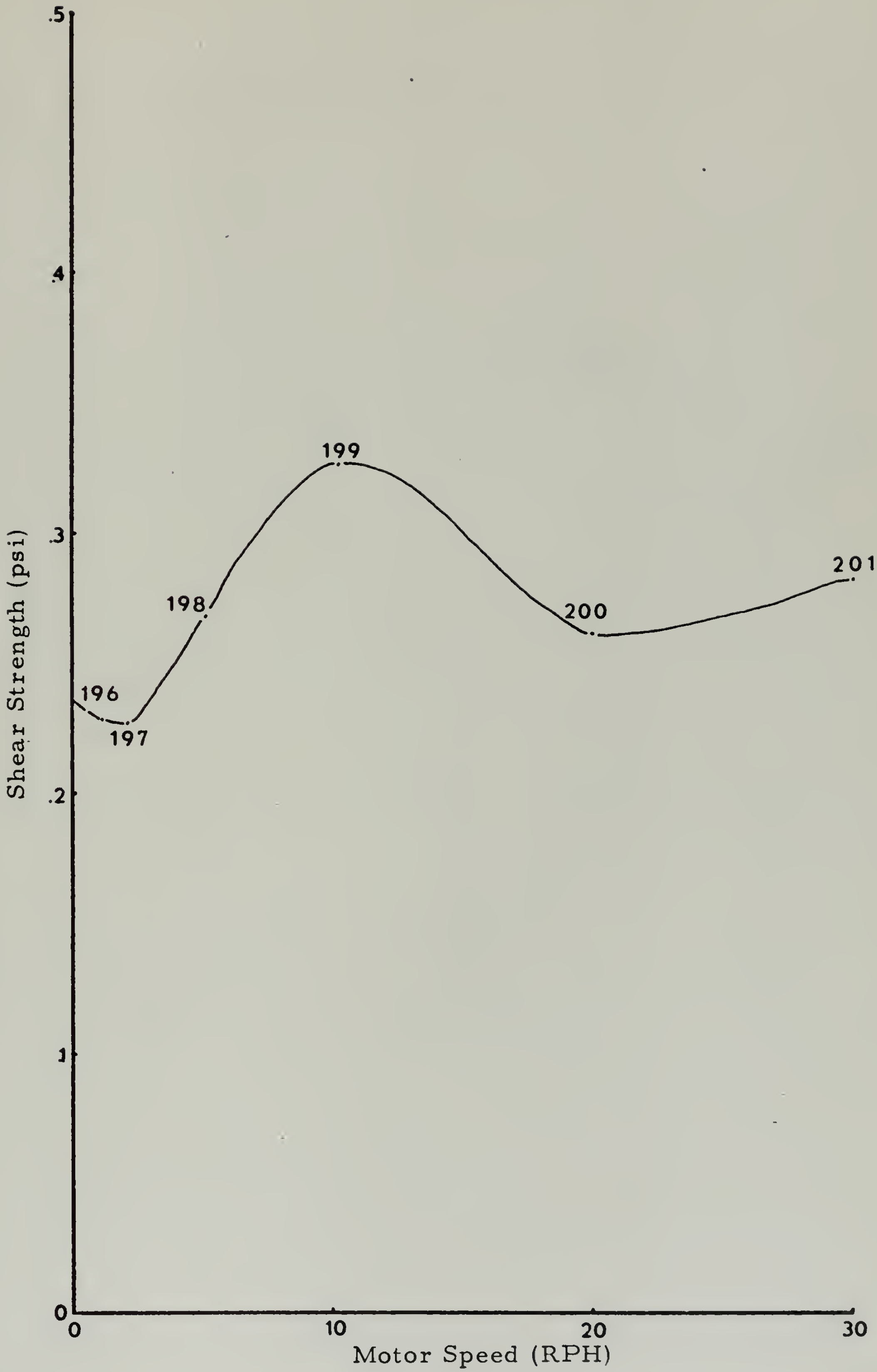


Figure 27. Shear Strength versus Motor Speed, Runs 196-201, Clay

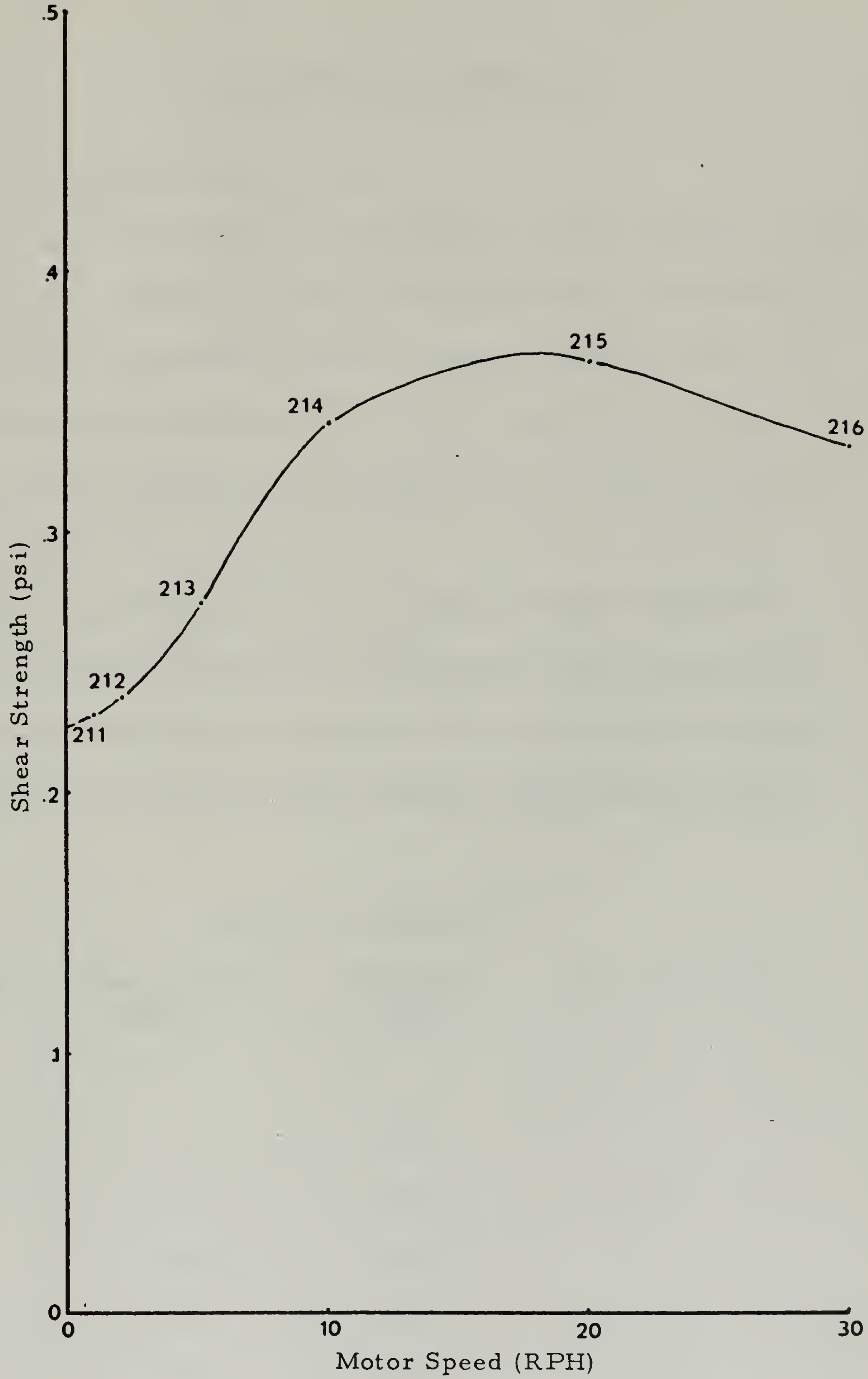


Figure 28. Shear Strength versus Motor Speed, Runs 211-216, Clay

V. DISCUSSION OF RESULTS

A. SIZE OF SAMPLE CONTAINER

The suggestion of Osterberg [1957] that, in order to obtain accurate values of shear strength, the vane area be less than 10 per cent of the circular area of the sample results in a ratio of the diameter of the sample to the diameter of the vane of 3.16. Containers 4 through 7 had ratios greater than 3.16 while containers 1, 2, and 3 had ratios less than this value.

If it is assumed that the values of shear strength obtained for container 7 in Figures 12 and 16 are the most accurate measure of shear strength for the samples tested, the area of the vane being less than one per cent of the area of the container, the following errors result:

Runs 91-97 (Figure 12)

Container	Shear strength (psi)	Difference (psi)	Per cent error
7	.197	0	0
6	.206	.009	4.57
5	.242	.045	22.8
4	.2295	.0325	16.5
3	.231	.034	17.3
2	.264	.067	34.0
1	.286	.089	45.1

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Runs 217-222 (Figure 16)

Container	Shear strength (psi)	Difference (psi)	Per cent error
7	.1818	0	0
6	.2015	.0197	10.8
4	.2183	.0365	20.1
3	.2593	.0775	42.6
2	.263	.0862	47.4
1	.305	.1232	67.8

Disregarding the results for container 5 (the solid curve of Figure 12), the errors for the case where the vane area is greater than 10 per cent of the sample area vary from approximately 17 per cent up to 67.8 per cent. Errors for the case where the vane area is less than 10 per cent of the sample area are generally less than 20 per cent.

B. NUMBER OF BLADES

Figures 17 through 23 show maxima of shear strength between three and five blades. The two-bladed vane generally gave the lowest value of shear strength. From these minima, shear strength increased to the maxima, then decreased for the vanes with more than five blades. The increase in shear strength for vanes with three and four blades is thought to be caused by the additional area acting to shear the sample. After the maximum shear strength was reached at approximately four blades the subsequent decrease in shear strength is attributed to the

fact that the sample was disturbed to a greater extent by the vanes with more than four blades.

C. MOTOR SPEED

Review of Figures 24 through 28 shows a general increase in shear strength with increased motor speed. The values of shear strength for 1 and 2 RPH do not differ by more than 3.52 per cent (Runs 174 and 175).

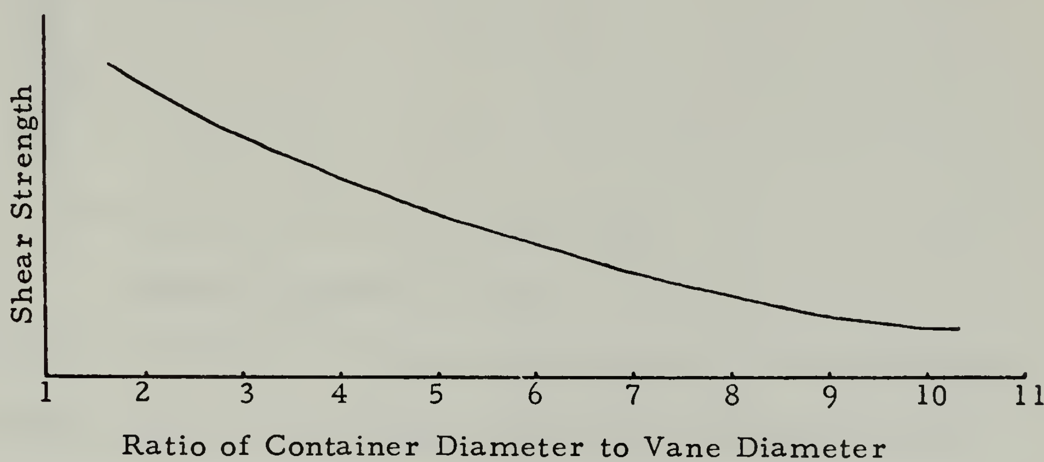
Of particular note in Figures 27 and 28 is the fact that extending the curves back to the ordinate axis of 0 RPH (corresponding to a vane turning at an infinitely slow rate) gives almost the same value for the intercept. This is believed to represent a valid comparison for the clay because of its homogeneity and the fact that the clay was always maintained at room temperature. This comparison was not made for the grease because of the great variation in the results of successive series of tests due to different temperatures and heating and cooling times.

Averaging the values of the intercepts (.2290 and .2265 psi) gave a value of shear strength of .2278 psi for 0 RPH. The values of shear strength for a motor speed of 1 RPH were .2268 (Run 196) and .2295 psi (Run 211). These values differ from .2278 psi by .439 per cent and .746 per cent respectively. For a motor speed of 2 RPH (Runs 197 and 212) the differences were .834 per cent and 3.38 per cent respectively.

VI. CONCLUSIONS

The results of vane shear tests are influenced by the relative size of the sample container, the number of blades on the vane, and the speed of the motor turning the vane.

A typical curve of shear strength versus ratio of container diameter to vane diameter, with no attempt made to assign values along the ordinate, would be as shown below.

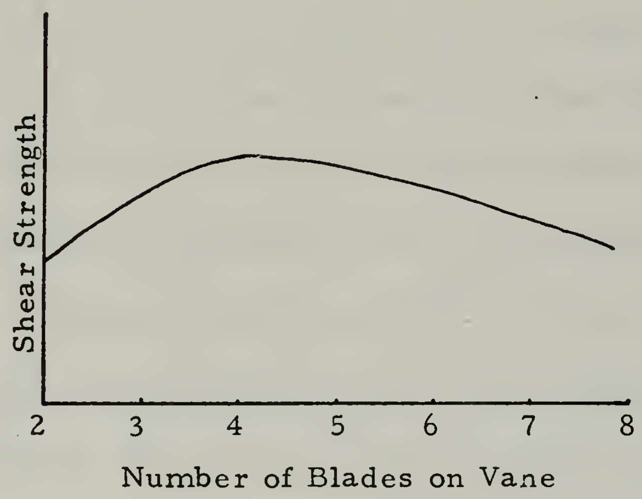


In order to obtain accurate results in a vane shear test on marine sediments the ratio of sample container diameter to vane diameter should indeed be greater than 3.16 as stated by Osterberg [1957]. This ratio would give results which are in error less than 20 per cent. To reduce the error to less than 10 per cent, a ratio greater than 7 would be required.

Previous testing conducted with ratios of the diameter of the sample container to the diameter of the vane less than 3.16 may be corrected

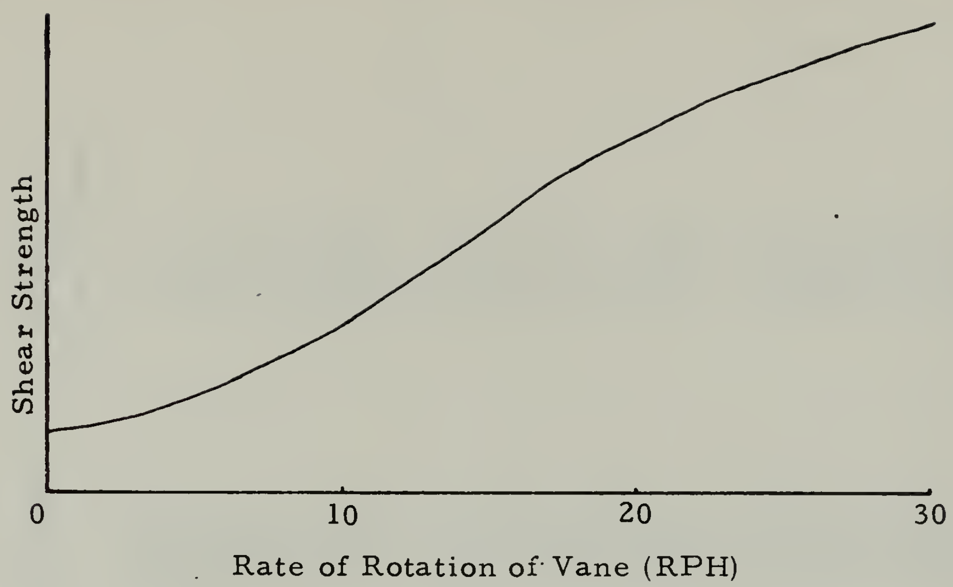
by applying a suitable factor obtainable from the solid curve of Figure 12. This would discount the results obtained with container 5 for that series of tests and thus result in a smooth curve.

A curve typifying the plot of shear strength versus number of blades of the vane, with no values assigned along the ordinate, would be as shown below.



The above curve indicates that the most accurate determination of shear strength is made using the four-bladed vane in agreement with current practice. This vane gives the best value for shear strength and is easier to manufacture than most vanes with a different number of blades.

The representative plot of shear strength versus turning rate of the vane, with no values assigned along the ordinate, is as shown below.



The curve shows the value of shear strength for turning rates of 1 and 2 RPH to be essentially equal, but the value of shear strength increases with rates exceeding 2 RPH. Turning rates of 1 and 2 RPH are currently employed in vane shear tests. Both of these rates give valid results of shear strength, but any higher speeds of rotation would give erroneously high values.

APPENDIX A

Results of Tests

Run No.	Mat'l	Speed (RPH)	No. of Blades	Container	M_{max} (mv)	Shear Strength (psi)
56	grease	1	4	1	85.5	.364
57	"	"	"	2	109.0	.464
58	"	"	"	3	78.6	.334
59	"	"	"	4	52.8	.2245
60	"	"	"	5	51.6	.220
61	"	"	"	6	33.0	.1404
62	"	"	"	7	35.5	.151
63	grease	1	4	1	103.6	.441
64	"	"	"	2	80.0	.340
65	"	"	"	3	51.0	.217
66	"	"	"	4	70.8	.3015
67	"	"	"	5	67.8	.288
68	"	"	"	6	49.9	.212
69	"	"	"	7	48.1	.2045
70	grease	1	4	1	60.2	.2565
71	"	"	"	2	51.2	.218
72	"	"	"	3	50.7	.216
73	"	"	"	4	55.1	.2345
74	"	"	"	5	48.7	.207
75	"	"	"	6	46.5	.198
76	"	"	"	7	57.7	.2457

Run No.	Mat'l	Speed (RPH)	No. of Blades	Container	M_{max} (mv)	Shear Strength (psi)
77	grease	1	4	1	69.0	.294
78	"	"	"	2	75.0	.319
79	"	"	"	3	63.0	.268
80	"	"	"	4	45.7	.1947
81	"	"	"	5	63.8	.2715
82	"	"	"	6	52.0	.2215
83	"	"	"	7	60.6	.258
84	grease	1	4	1	62.0	.264
85	"	"	"	2	67.5	.287
86	"	"	"	3	53.0	.2255
87	"	"	"	4	52.5	.2235
88	"	"	"	5	58.7	.250
89	"	"	"	6	54.7	.2325
90	"	"	"	7	46.7	.1988
91	grease	1	4	1	67.2	.286
92	"	"	"	2	62.0	.264
93	"	"	"	3	54.3	.231
94	"	"	"	4	53.9	.2295
95	"	"	"	5	57.0	.242
96	"	"	"	6	48.8	.206
97	"	"	"	7	46.3	.197

Run No.	Mat'l	Speed (RPH)	No. of Blades	Container	M_{max} (mv)	Shear Strength (psi)
98	grease	1	4	1	71.0	.302
99	"	"	"	2	72.0	.306
100	"	"	"	3	65.0	.2765
101	"	"	"	4	48.5	.2063
102	"	"	"	5	49.7	.2115
103	"	"	"	6	53.7	.2283
104	"	"	"	7	51.3	.2182
105	grease	1	2	A	53.1	.226
106	"	"	3	B	69.8	.297
107	"	"	4	C	69.9	.2975
108	"	"	5	D	65.1	.2767
109	"	"	6	E	58.0	.2467
110	"	"	7	F	77.0	.3275
111	"	"	8	G	50.9	.2165
112	grease	1	2	A	59.1	.2515
113	"	"	3	B	58.0	.2465
114	"	"	4	C	70.5	.300
115	"	"	5	D	68.9	.293
116	"	"	6	E	69.2	.294
117	"	"	7	F	90.7	.386
118	"	"	8	G	67.0	.285

Run No.	Mat'l	Speed (RPH)	No. of Blades	Container	M_{max} (mv)	Shear Strength (psi)
119	grease	1	2	A	52.5	.2235
120	"	"	3	B	56.5	.2403
121	"	"	4	C	65.8	.280
122	"	"	5	D	64.0	.272
123	"	"	6	E	54.9	.2335
124	"	"	7	F	78.5	.334
125	"	"	8	G	61.0	.2597
126	grease	1	2	A	50.7	.2155
127	"	"	3	B	53.3	.227
128	"	"	4	C	58.3	.248
129	"	"	5	D	56.4	.240
130	"	"	6	E	58.6	.2495
131	"	"	7	F	66.0	.281
132	"	"	8	G	61.5	.2617
133	grease	1	4	A	64.2	.2735
134	"	2	"	B	65.5	.279
135	"	5	"	C	65.5	.279
136	"	10	"	D	75.5	.3215
137	"	20	"	E	94.0	.400
138	"	30	"	F	101.0	.429

Run No.	Mat'l	Speed (RPH)	No. of Blades	Container	M_{max} (mv)	Shear Strength (psi)
144	grease	1	4	A	52.1	.222
145	"	2	"	B	51.3	.2185
146	"	5	"	C	64.6	.2755
147	"	10	"	D	77.3	.329
148	"	20	"	E	80.0	.3405
149	"	30	"	F	89.3	.380
156	grease	1	2	A	64.5	.2745
157	"	"	3	B	68.0	.2896
158	"	"	4	C	58.0	.247
159	"	"	5	D	62.8	.2675
160	"	"	6	E	62.0	.264
161	"	"	7	F	70.3	.2995
170	clay	1	4	1	52.0	.2217
171	"	"	"	2	45.8	.195
172	"	"	"	3	43.0	.183
173	"	"	"	4	37.6	.160
174	grease	1	4	A	66.6	.284
175	"	2	"	B	64.3	.274
176	"	5	"	C	69.0	.294
177	"	10	"	D	92.3	.3935
178	"	20	"	E	101.5	.432
179	"	30	"	F	82.0	.3493

Run No.	Mat'l	Speed (RPH)	No. of Blades	Container	M_{max} (mv)	Shear Strength (psi)
180	clay	1	4	1	48.4	.206
181	"	"	"	2	56.0	.2383
182	"	"	"	3	64.4	.2742
183	"	"	"	4	54.3	.2313
184	"	"	"	6	43.8	.1867
185	"	"	"	7	42.3	.180
189	clay	1	2	A	41.3	.176
190	"	"	3	B	46.6	.1985
191	"	"	4	C	48.8	.208
192	"	"	5	D	56.5	.242
193	"	"	6	E	51.0	.2173
194	"	"	7	F	50.0	.213
195	"	"	8	G	50.5	.215
196	clay	1	4	A	53.3	.2268
197	"	2	"	B	53.0	.2259
198	"	5	"	C	62.5	.266
199	"	10	"	D	76.2	.3245
200	"	20	"	E	60.9	.2595
201	"	30	"	F	66.0	.281
203	clay	1	2	A	39.0	.166
204	"	"	3	B	55.9	.238
205	"	"	4	C	51.6	.220
206	"	"	5	D	51.0	.2173
207	"	"	6	E	55.7	.237
208	"	"	7	F	57.3	.242
209	"	"	8	G	53.9	.2295

Run No.	Mat'l	Speed (RPH)	No. of Blades	Container	M_{max} (mv)	Shear Strength (psi)
211	clay	1	4	B	53.9	.2295
212	"	2	"	C	55.3	.2355
213	"	5	"	D	64.0	.2723
214	"	10	"	E	80.0	.3405
215	"	20	"	F	85.5	.364
216	"	30	"	G	77.8	.3313
217	clay	1	4	7	42.7	.1818
218	"	"	"	6	47.3	.2015
219	"	"	"	4	51.3	.2183
220	"	"	"	3	60.9	.2593
221	"	"	"	2	63.0	.268
222	"	"	"	1	71.6	.305

BIBLIOGRAPHY

Aas, G., "A Study of the Effect of Vane Shape and Rate of Strain on the Measured Values of In-Situ Shear Strength of Clays", Norwegian Geotechnical Institute, Publication No. 65, p. 5-9, 1965.

Cadling, L., and Odenstad, S., "The Vane Borer, An Apparatus for Determining the Shear Strength of Clay Soils Directly in the Ground", Royal Swedish Geotechnical Institute, Proceedings No. 2, 1950.

Heck, J. R., Engineering Properties of Sediments in the Vicinity of Guide Seamount, MS Thesis, Naval Postgraduate School, Monterey, California, 1970.

Minugh, E. M., A Versatile Vane-Shear Apparatus, MS Thesis, Naval Postgraduate School, Monterey, California, 1970.

Morelock, J., Sedimentation and Mass Physical Properties of Marine Sediments, Western Gulf of Mexico, Ph. D. Thesis, Texas A&M University, May 1967.

Osterberg, J. A., Introductory Comments, Symposium on Vane Shear Testing of Soils, American Society for Testing Materials, Special Technical Publication No. 193, 1957.

Smith, R. J., "Engineering Properties of Ocean Floor Soils", ASTM Symposium on Field Testing of Soils, American Society for Testing Materials, Special Technical Publication No. 322, 1962.

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13. ABSTRACT

The consequences resulting from varying the parameters of the vane shear test (used to determine the shear strength of marine sediments) were investigated. Experiment showed that larger ratios of container diameter to vane diameter yield more accurate shear strengths. It was also shown that the four-bladed vane produced the best results. Finally, rates of rotation of one and two revolutions per hour were found to give accurate values of shear strength, while higher rates of rotation proved to be unsatisfactory.

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